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This report considers universities as information systems because their effective operation is based on the storage, processing, and communication of various types of information. Three basic types of information systems (administrator-, teacher-, and researcher-oriented) are discussed in an attempt to understand each system's operation from the point of view of its basic objectives and the information processing necessary to achieve these objectives. The use of computers to aid this processing is also discussed. The report views the university as a totality of many diverse information systems which are interdependent and interrelated, a concept which leads to the proposal that a single centralized information system be established using a computerized data base with remote access by the various users. The possible uses of such a system are discussed. A bibliography of 102 items related to the three basic types of information systems is attached. (JW)

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INFORMATION SYSTEMS IN UNIVERSITIES

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(Research Report)

INFORMATION SYSTEMS IN UNIVERSITIES

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1885

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Vladimir Slamecka

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Abstract

Universities are information systems because their effective operation is based on the storage, processing, and communication of various types of information. The basic types of information are Administrator, Teacher, and Researcher-oriented. Each of these information systems is developed in the paper in an attempt to understand its operation from the point of view of its basic objectives and the information processing necessary to achieve these objectives. The use of a digital computer as an aid to information processing is discussed at appropriate places in the exposition.

The paper is structured around the theme of viewing a university as a totality of many diverse information systems which are interdependent and related to one another. The managerial revolution in higher education, the pressures from government and industry, and the increasing social demands on the university combine to form a favorable climate for a total systems approach to analyzing the university. This report reviews this environment, discusses and postulates conceptual designs for the major university information systems, and gives recommendations for what can be done now to begin to upgrade the processing of information in the university. The report ends with a short summary and a bibliography of articles and books which discuss topics germane to university information systems.

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INTRODUCTION

Background and Approach.

Education is "big business" in the United States. Over twenty-five per cent of our population now enjoy the benefits of some form of education. In 1965 expenditures for education totaled 35 billion dollars. The only endeavor which financially outranks education in the U.S. is national defense.

The tremendous growth of our economy, the information explosion, and student unrest have placed a number of pressures on the structure and operation of all types of educational institutions. This report is concerned only with institutions of higher learning. On the pages of this report we discuss how the information systems of the university can be better structured to meet the challenges of the present and the predictable future.

The administrators of universities now manage information systems which have greatly expanding data bases and are required to cope with situations which demand quicker and quicker quantitative solutions. The net result of these factors is that more and more credence is being given to computer-based techniques such as management information systems, modeling and simulation, and a systems approach (based on the use of a computer). The unparalleled growth of all types of information in colleges and universities (hereafter the institution of higher learning is referred to as a university) is indicated by the increasing number of computers used in these institutions. In 1967 thirty per cent of all universities had one or more components; by 1970, it is predicted that half of all universities will have at least one computer to assist in handling its information. In 1968 the total value of all computers in universities was over one-half billion dollars.

This report presents a systems approach to viewing, studying and designing a university as a system which is composed of several information systems which process information related to - Administration, Teaching, and Research. The systems approach was chosen as the central theme because a comprehensive approach was essential in order to cope with the diverse informational problems inherent in most universities today.

The internal environment of most universities is now undergoing rapid transition. The increasing number and demands of students and faculty, the expanding curricula and physical facilities and the introduction of computer-based information systems make university administration a most stimulating and challenging profession. University professors are not without their challenge in the use of new teaching techniques, such as computer assisted instruction, packaged TV lectures, and audio-visual aids to assist them in the instruction process. Researchers have an exciting future in their use of "automated" libraries to retrieve desired information. We can safely conclude that the university is a growing and a dynamic institution, struggling to cast off the inefficiencies of the past and striving to refine its objectives and its mission in the life of its community.

The change in the structure or the operation of a university does not come about easily and effortlessly. There are many factors that tend to resist change. Some of these are beneficial in that they serve as a check against premature, unnecessary, or unsound alterations in the system. Other resistance factors are detrimental because they may prevent the system from changing when some change is necessary for its survival. The basic question is this: Are the changes which the universities are undergoing today well-planned and are they centered around the processing of information? The conditions are perfect to implement the required changes in such a way as to upgrade and modernize the basic information systems in the university. The paper presents an approach to the solution of this problem.

The University as an Information System

A university is an educational institution having the primary purpose of effectively educating its students. A university is frequently and accurately referred to as an information system in that it can be defined as:

(1) an interacting collection of elements which is

(2) designed to accomplish certain objectives by

(3) creating, storing, processing and communicating information.

The elements or components of a university can be considered to be teachers, administrative staff, students, libraries, buildings, facilities and many other basic system entities. These elements interact and relate to one another in various combinations by using information supplied to them by different types of information networks. These information networks provide the necessary binding force which allows the system to accomplish certain objectives. A system composed of one or more information networks is called an information system.

The "substance" which flows in various forms over the information networks is called information. As a basic unit it can be considered to be knowledge concerning some particular fact, subject, or event, in any communicable form which has meaning to an individual or a group. This flow of various types and forms of information is vital to the operation of all parts of the university. For example, without appropriate information networks

- the administrator would be unable to make decisions, for he would have no information concerning alternatives.
- the student would be stiffled in his attempts to learn, for the instructor could not communicate with him.
- the researcher could not build on the works of others, for the information stored in the library would not be available to him.

The study of an information system is best begun with a knowledge of its objectives or goals. The objectives of most universities can be classified into direct and indirect categories. The direct objectives are those which in one way or another relate to 1) instruction, 2) research, 3) service to the public and academic community. The main indirect or internal objective is to sustain the university itself through appropriate administrative or managerial activities. In the final analysis all objectives are achieved through numerous activities as functions performed by the elements of the system.

A university could not adequately sustain itself without administrators who are sensitive to the information needs and data bases of the institution. The administration of a university is not unlike the management of a company and therefore general management practices and concepts can be applied directly to university managers. We know that management is primarily a decision making activity and the basic input to the decision process is information. In fact, a manager can be defined as a person who converts information into action. Without information effective decision making is impossible. Thus, the effectiveness of any information system used by management is in its ability to present accurate, useful, and timely information to the decision makers. These ideas are fundamental in the consideration of Administrative Information Systems.

Without its information systems a university would cease to exist. They provide the data base, the information networks and the necessary functions by which the parts of the university communicate with one another and form a totality with its own identity. The information systems in the university are in many ways similar to the information systems in the human body. For example, the central nervous system handles the second by second administrative details for the body as it operates in a particular environment. The glandular system processes information related to the longer term interval conditions and mission of the body itself and is similar to the teaching and research systems which do not change quite so quickly. The analogy is not perfect, but it does emphasize the important role played by the information systems of both the human and the university.

There are several ways to subdivide the overall university information system into smaller, more manageable units. Some of these are: by organizational level, by geographic location, by major files in the data base, by major functions, and by overall system objective. Since most information networks in universities tend to separate themselves into administrative, teacher, and research-oriented components, this breakdown was selected for this report. Within each of these systems, a functional approach will be taken to describe the activities at the next level of detail.

University Information Systems.

Abstractly, an information system can be represented as a directed graph having a set of nodes (elements) and a set of relationships between the nodes (information flows). This closely parallels a mathematical definition of a system - a set of elements (E) and a subset (relations) of the Cartesian product space (ExE). In a university the nodes represent an individual, a department, or a data base; the relationships represent information flows such as the information an individual requires from a data base or the information a department supplies to the teachers in the department.

In setting up an information system based on the above definition, some clusters or groupings of "related" elements can be observed. These groups tend to be distinguished by the type of information which is common to each.

The process can lead to the establishment of information systems which are common to each group. It should be noted that the grouping is not unique and depends on how an individual constructs his graph. The three information systems discussed below are the usual results obtained by this grouping procedure.

Administrative Information System (AIS). All the data bases and information flows which are required to handle the administrative affairs of the university are contained in this information system. The processing of administrative information has been the central theme of most of the work that has been done to date in university information systems. Section II and the articles referred to in the AIS bibliography are primarily oriented to systems which store, handle, update, create or communicate administrative information.

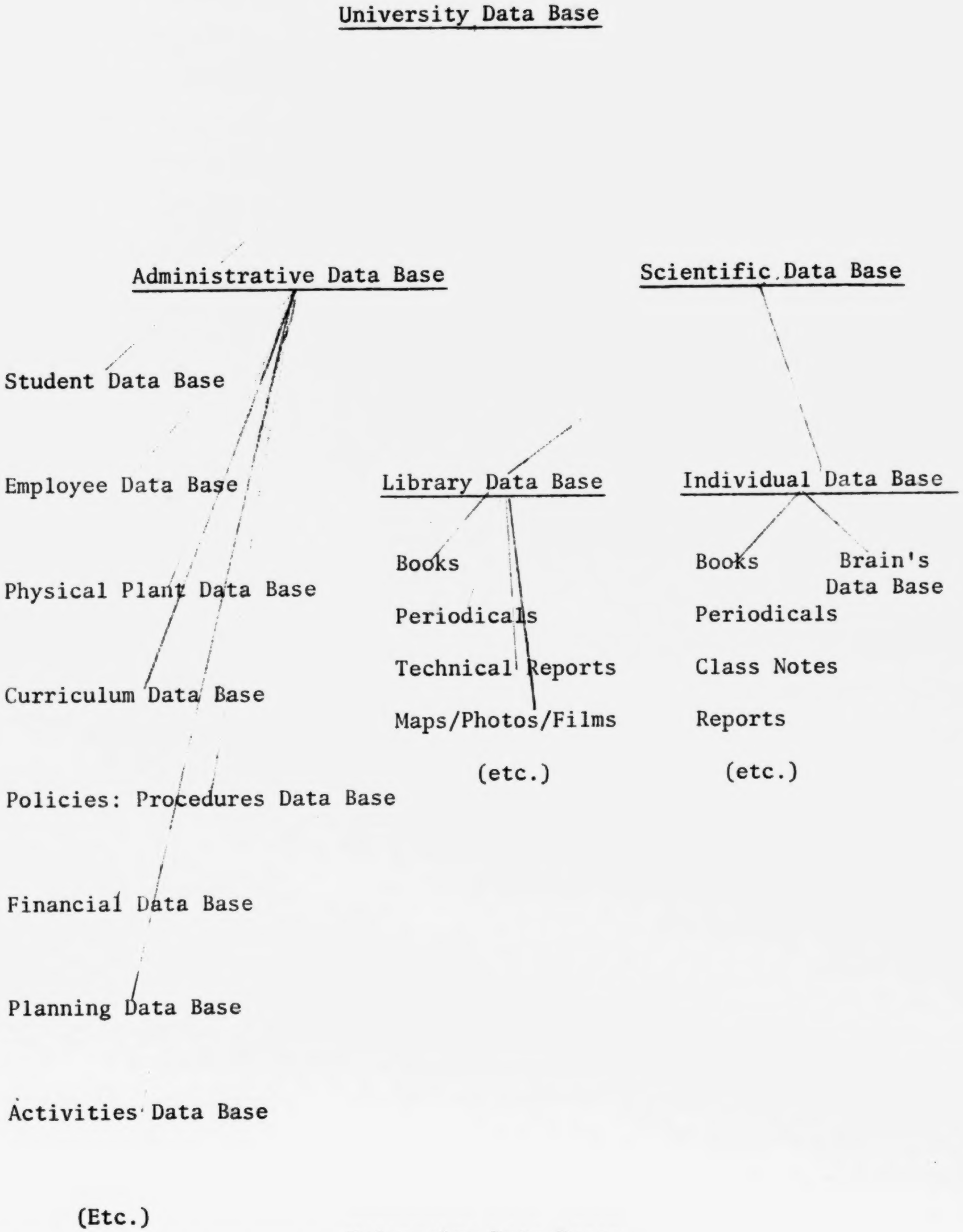
Teaching Information System (TIS). The primary objective of most, if not all, universities is to effectively instruct its students. Recently some emphasis has been placed on new techniques of instruction, but little attention has been paid to studying the entire instructional process and designing information systems to assist the teacher in his major activity --handling and communicating information.

An instructional information system would be oriented around the scientific data base and the files in that data base that contain information related to the courses taught at the university. For example, a professor may structure a course in the following manner: video tape his main lectures and prepare a programmed instruction text for the difficult concepts to be presented in the class. When taking the course, the slow student may view the lecture again on TV and/or use the programmed instruction material for more instruction on those points he doesn't understand.

Research Information System (RIS). In many ways this information system is similar to the Teaching Information System. At times a teacher may need to use the research system, but his job is primarily instruction; whereas the researcher is oriented toward creative work frequently on very specific topics. The researcher requires information from the scientific data base and supplies information to this data base in the form of his documented research. A research information system must provide a means of searching the scientific data base for all applicable material related to a researcher's interests. This is a difficult requirement to meet economically because of the volume of material, most of which is not in machine readable form.

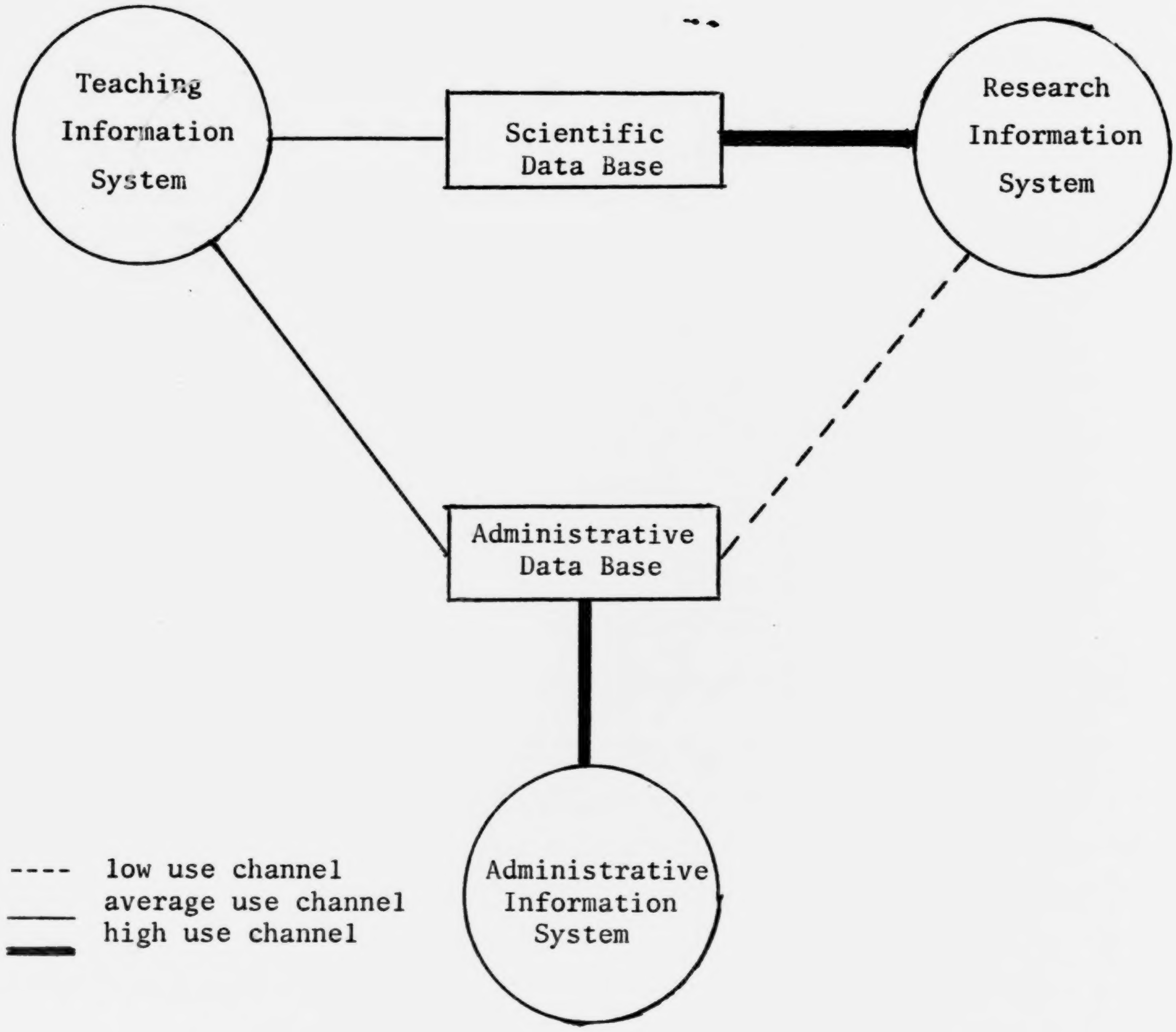
University Data Bases

The storage of information (commonly called a data base) in a university can take many different forms but can be subdivided in a hierarchal fashion. As a first level dichotomy of the types of information necessary


University Data Base
Administrative Data Base
Scientific Data Base
Student Data Base
Employee Data Base
Physical Plant Data Base
Curriculum Data Base
Policies: Procedures Data Base
Financial Data Base
Planning Data Base
Activities Data Base
(Etc.)
Library Data Base
Books
Periodicals
Technical Reports
Maps/Photos/Films
(etc.)
Individual Data Base
Books
Brain's Data Base
Periodicals
Class Notes
Reports
(etc.)

University Data Bases

Figure 1.


Teaching Information System
Scientific Data Base
Research Information System
Administrative Data Base
Administrative Information System
---- low use channel
average use channel
high use channel

University Information Systems and Data Bases

Figure 2

in the university system, we separate the administrative date base from the body of information primarily contained in the library and in individual files. This latter data base we call "the scientific data base." See Figure 1 for a breakdown of the major university data bases,

The administrative data base contains all information required for managing the affairs of the university. This includes the information related to people, physical plant, money, program and activities. This data base in conjunction with the appropriate processing system becomes the administrative information system for the university and supports the secondary objective of the university - that of sustaining itself.

The scientific data base supports the primary objectives of the university. In conjunction with the human data storage system, the brain, this scientific data base is essential to the instructional and research objectives of the university. This data base is difficult to structure and its tremendous volume prohibits it from being kept in machine readable form. However, there are ways to reduce the volume (microform) and means of indexing (keyword) which provide for either manual or computerized access to the material.

The data bases contain facts which, when processed by the university information systems, yield information necessary to the successful operation of the university. The overall relationship between the data bases and the information systems is shown in Figure 2.

Information-Based Problems in Universities

Many of the problem situations in universities are the result of inadequate design or unplanned evolution of its numerous information systems. Since universities themselves are information systems, the effective storage, processing and communication of information should be of paramount concern to those individuals who are part of the system. The following major problem areas which are present in many universities today have been caused by informational breakdowns in one or more of the university's information systems.

1. Duplication of Records and Files. There is a natural tendency for the duplication of records between and within departments in organizations in which the central repository (if one exists) is unable to satisfy the demands leived on the system. This duplication is typified by the large number of copies which are required to record various events or activities. In a totally designed system, duplication might occasionally be required for some records, but such activities would be minimized over the system.

2. Lack of Procedure Standardization. Almost all organizations have specified procedures for handling and filing information. However, as the organization requires new files and makes changes to old ones, the old procedures may not be correspondingly updated to maximize the processing of the new information. This results in such problems as loss of material through misfiling, redundant operations, and unnecessary copies. The longer these inefficiencies are allowed to continue, the more chaotic they become and the harder it is to change them. A completely new system is usually the best approach in replacing a system full of outdated operations and procedures.

3. Unclear or Overlapped Objectives. A universally accepted tenet of good management is that a manager must define the requirements and the limits of authority for a subordinate position. If this is unambiguously done, then the occupant of the subordinate position is free to determine his objectives within the specified limits. This management practice results in a minimum overlapping of duties and provides an excellent means for managerial evaluation. Unfortunately, there is a considerable amount of fuzziness and vagueness about the objectives and limits of many university administrative, teaching and research positions. This type of definitional information must be created and updated in a goal-oriented organization, and there must be information systems ~~avail~~able which are capable of storing, retrieving and communicating it.

4. The Relationship between Academicians and Administroators. As any human organization grows, administrative functions become more time consuming and at the same time become more critical for the proper functioning of the organization. In small organizations, the technical people

can usually handle administrative duties along with their technical work. However, a certain critical point is passed in the size of an organization when different types of people are required for the different functional jobs.

Over the years in some large institutions of higher learning a "concern" has evolved between the administrators and the academicians as to who has control over the university. The academicians claim that important decisions are sometimes made without their knowledge or approval, and the administrators counter with statements that they have had to act unilaterally because of the requirements levied on them by their office. There is some justification for both points of view, but in the final analysis both groups are essential to fulfill the mission of the university. This conflict is primarily a communications problem and could be eased considerably with adequate information systems. Appropriate information systems would contain and supply current information to members of both groups and would certainly aid in the free exchange of all types of information.

Current Design Approaches to University Information Systems

As one would expect, there are numerous considerations in the design of a new or revised university information system. Any design group will have to define its tasks with respect to the following major design considerations:

- Resources available for the design effort
- Magnitude of the design effort
- General philosophy of design
- Extent of computer use in the new system
- Time-phased design *vs* turn key operation
- Placement of the design group in the university organizational structure.

Before a design group can commence any actual design activities, it must have established some guidelines for each of the above considerations.

Many past design efforts have been of an *ad hoc* variety and have probably added more confusion than order to the overall processing of of information in the university. For example, suppose a computerized class scheduling capability were desired to replace the present non-computerized version in a typical university. In most cases a small design group of programmers would be assembled and a program and a system would be designed to accomplish the most efficient class scheduling from the registration information. But what about the other aspects of registration such as payment of fees and the enrollment in non-academic activities? These information systems probably would suffer because of the narrow mission given the class scheduling design group.

In order to present a survey of current methods by which university systems or subsystems are designed today, we have summarized the numerous design approaches into four categories. These categories represent the basic philosophies of design for those systems which use computers in some type of information handling capacity. They are designs oriented around:

- The computer
- The organizational chart
- The data base
- The information systems

1. Designs oriented around the Computer. In this approach a manual (or unit-record) system already exists and the new system simply automates the old data base "as is" on a general purpose computer system. There is no original design in that the new information system is just a faster version of the older one. This design approach is frequently used in the following university situations:

- The financial department of the institution initially obtains a computer to aid in accounting. Before long other areas secure time on this machine for automating their own manual files.
- A large computer system is obtained by the university and placed under a single (sometimes self-contained) department. All departments are notified of the acquisition and are allowed to submit their own computer program to be processed by the machine.

The designs for these piece-meal uses of the computer are usually implemented in stages and result in a fairly small disruption of the established information networks. They have the disadvantage of being too narrow in scope and tend to separate most of the old inefficiencies in the computerized version. One of the professional conferences which tends to publish articles describing systems which use this approach is the Machine Records Conference. The papers presented at these conferences tend to be directed to specific problems and how these problems have been solved by using either computers or punched card equipment.

2. Designs oriented around the Organization Chart. Some information flows in a university are automatically created and structured by the organization chart. Many universities have different information systems for each separate department or office. In these situations it is usual that each department determines its own data base and operating procedures. If the processing load becomes sufficiently large, the department either obtains its own computer or shares a computer with other closely related departments.

This is a common approach used in universities where uneven allotments of resources are permitted. It allows individual areas to determine their own information requirements as though they were autonomous units. As a result of this type of environment, overall university information systems suffer through the duplication of effort and the existence of parallel (although, perhaps slightly different) data bases.

3. Designs oriented around the Data Base. An information system (manual or computerized) which already exists is frequently analyzed for incorporation into a new system by organizing the data base elements into meaningful categories. It is possible to arrange these categories into a structure which is compatible with the organization's structure. The categories should be analyzed one by one, all redundancies removed, and a computer file established for each. Appropriate computer programs are then written to maintain and query the file and all interested departments are sent information on how to use the computerized file. This is an approach used by many systems people for the purpose of eliminating redundant information. It is a useful first step, but frequently the design

effort gets bogged down in implementing an immediate result and the total design is never achieved.

4. Designs oriented around the Information Systems. This approach is very comprehensive in that the entire university is studied to determine the various types of information which flow over its information networks. This overall approach results in a universal design which has eliminated most, if not all, of the inefficiencies and redundancies resulting from more limited viewpoints. The design need not be automated but frequently is because of the speed and volume requirements of the larger volumes of data and the response time required. As a goal, we desire that all parts of the system work together and support each other to accomplish the overall system objectives. Thus, the information system approach is a total systems approach. According to two authorities on university information systems, John Caffrey and Charles Mosmann, in their book Computers on Campus [A12],

> "The total systems approach is really characterized by a state of mind, a set of attributes and objectives and a widely shared intention to design each part and phase of the system, whether sequentially, or all at once, or whether in the same department or several, so that it fits neatly and helpfully with every other."

Several indirect benefits are obtained by using the information systems approach to design. A system can be improved upon and automated only when it is thoroughly understood, and it can be thoroughly understood only when all the interrelationships and information flows are known. In designing an automated system, the administrator is called upon to think seriously about his objectives and his means of achieving them. It has been said that this process alone, when required of everyone in the organization, is usually worth the cost of the effort.

Design and Implementation Problems for Total University Information Systems

The total systems approach discussed in this paper has been presented from a positive point of view. If correctly used, it will tend to optimize the objectives of the entire system, reduce redundancies, allow the information systems to grow, and provide for many services not possible in less extensive approaches. However, there are some significant factors which tend to oppose such an all-encompassing activity. These factors are briefly discussed under the following headings:

- 1. Uninformed Staff
- 2. Shortage of Systems Personnel
- 3. Economic Constraints
- 4. Historic Conservatism in University Management

1. Uninformed Staff. In many organizations, in private industry as well as in the university, there are few or no persons on the staff who have adequate training in the methods of information science or who are in a position to know or suggest better, more advantageous ways of processing information. People generally tend to be buried in their own specific problems and don't have a chance to investigate the workings and interrelationships of all parts of the system. Even if an individual is partially informed on the overall benefits of a total systems approach, he may object on philosophical or psychological grounds. Numerous psychological feelings are aroused in an individual when he is informed that some of his routine jobs can be performed faster, cheaper and more accurately on a computer. An uninformed or an ill-informed staff represents a serious drawback to the total systems approach.

2. Shortage of Systems Personnel. Well-qualified information scientists are in short supply. They usually command high salaries in industry and are not attracted to the slightly lower paying positions in a university. Programmers, per se, can be trained in two or three years to a reasonable level of proficiency, but a systems designer must be mellowed with time and experience. The pressure on the system designers and on an organization which undertakes a total approach to designing new systems is tremendous. One reason for this is that if the new system is not successful, the organization stands to lose a great deal in terms of time, prestige and money. This is the primary reason why companies and universities are hesitant to commit themselves to the possibility of such a calamity. It should be realized, however, that good designers will tend to produce a system in which the payoff many times outweights the risk.

3. Economic Constraints. Computers and their related systems are expensive items for any organization. The cost for qualified people is also high. In fact, a rule of thumb used by many computer people is that the software (the people, supplies, etc.) for a computer center is almost as expensive as the hardware (the computer itself). Even with sizeable educational discounts for computers sold to universities, the overall costs are still staggering.

On top of this expense, the total systems approach requires a considerable long-term financial commitment. A comprehensive design may require several years of effort by many different people with very little immediate payoff. This is very difficult for budget-minded administrators to accept and usually results in increasing pressure to produce an interim product. This frequently succeeds and the organization obtains a partial system when the total system would have cost just slightly more. There must be a financial commitment by management for the complete design, and appropriate safeguards established to keep the design on a reasonable time schedule. A similar commitment is necessary for the implementation phase of the design once it has been accepted.

4. Historical Conservatism of University Administration. Universities are renowned for their creative research activities and their advancement and teaching of new theories and techniques. This might imply a rather aggressive management which would keep pace and even utilize some of the techniques it teaches. Ironically, this is not the case in most centers of higher learning. The administration is generally cautious in applying new concepts and to date have incorporated very few of the scientific management techniques.

Some changes are now being observed in university management, as pressure is applied from students, faculty, and society in general for more cost-conscious, objective-oriented operation. The total systems approach is a means by which all of these ideas can be combined into one unified information system for administration.

ADMINISTRATIVE INFORMATION SYSTEM

The need for a new approach to administrative information systems was clearly stated in the January, 1968, issue of the EDUCOM Bulletin. In the article on university information systems the following comment was made [A24]:

> "University administrators agree that a comprehensive information system is essential to the effective operation of a university. Few, however, are certain exactly what it should embrace. And, even among scholars who are knowledgeable about both administration and information systems, there is no consensus on the limits within which such a system can operate effectively."

This section attempts to place a structure on administrative information systems and establish some limits within which it can operate. It is based on the documented work done to date on the subject.

Most of the ideas relating to automated information systems for university administrative purposes can be traced to the development of management information systems in private companies. At the center of these information systems is a storage and retrieval system which contains not only an extensive data base, but is equipped with a flexible means of retrieving data from it. A manager can receive periodic reports or, if necessary, obtain on-line output for specific, ad hoc requests. Since the information demands levied on a university are in many ways equivalent to those realized in a company, company information systems could be considered models for the information systems used by a university.

Information systems, however, are more than a data base and direct retrievals from it. A total design of the overall system usually leads to many other uses of the data base. Once the bulk of the information in a system is in machine readable form, a number of additional capabilities or extensions can be realized for a marginal increase in design and implementation costs. Some of the most important extensions for an administration information system are discussed in The Computational Design of an Administartive Storage and Retrieval System.

The Managerial Revolution in Higher Education

There is a growing awareness by university administrators of the need to incorporate scientific techniques into university management. Because of the rather conservative tradition of university administration, this movement is viewed by some as a type of managerial revolution. Francis Rourke and Glenn Brooks writing in the Administrative Science Quarterly have the following to say about the revolution [A39]:

> "Recent innovations in the management of institutions of higher education represent a sharp departure from the traditionally conservative style of university administration. In a sample of state universities, the trend toward scientific management is illustrated by the emergence of offices of institutional research, the increasing reliance on quantitative data in policy analysis, and the use of computers in administration. Supporters of the new techniques contend that they will enhance the rationality of university decisions, while opponents charge that scientific management is irrelevant to most academic problems."

Offices of institutional research have been created in most large universities to obtain quantitative data on the educational or instructional process. These offices accumulate useful data but the data tends to be fractionated and is frequently used to fight administrative or political fires. The institutional research office usually lacks the authority or manpower to conduct comprehensive studies of the entire university.

John Hamblen sees an extended mission for these offices as that of system design offices for new university information systems. He writes [A20]:

> "If institutional researchers ever completely defined their role as presently viewed by the profession as a whole, they will at the same time have nearly defined an information system for an institution of higher education. Their existence today is necessary to compensate for poor data systems. They must keep pace with and adapt new techniques of data system development and management or they will be phased out as their institutions are able to attain a functioning management information system."

The above remarks lead to a reasonable conclusion in terms of the approach used in this report. The total systems approach documented herein does not necessarily require a new staff organized for its implementation, but can be achieved by extending the mission and resources of the office of institutional research. In addition to the analysis function, this enlarged office must also have a design and implementation role. This office should be responsible only to the president of the institution and should not be embedded somewhere several levels down in the organization hierarchy. Numerous studies have been made of such groups in private enterprises and the findings are that almost all successful total analysis and design groups report to the highest administrative office in the company.

Benefits of a Total Approach to Administrative Information Systems

The major benefit of a total information system is that it is primarily designed to accomplish those objectives which are required of the overall organization. It contains all the information required in the system and provides flexible means of retrieving the information to satisfy the users of the system. The design must also include effective ways of maintaining the active files and appropriate procedures for relegating unused information to secondary or historical repositories.

In a large and expanding university, a total administrative information system would necessarily be mostly computerized. The volume of information and the time demands on much of the material necessitate a computerized approach. Caffrey and Mosmann in their book Computers on Campus [A12]:

> "Growing institutions obviously generate more and more information, not only about increasing numbers of students and staff, but also about the problems of growth itself-facilities, library books, faculty recruitment, sources of revenue. In a manual system of administration every increase in enrollment of a hundred students may require another clerk. In an automated system such growth can often be accommodated simply by running the machine a few minutes longer."

The National Science Foundation recently sponsored multi-university research on the subject "Systems for Measuring and Reporting The Resources and Activities of Colleges and Universities." This research resulted in a document, called the Henle Report, in which most of the administrative aspects of the university were studied. This report is oriented toward establishing data base elements in a total systems context. The following comments are excerpts from this report [22]:

> "A university can be described as composed of a number of internal systems ..."
>
> "When one views the total institution as a single unit, encompassing all its activities, one is viewing the organization as 'total systems' ... "
>
> "a total information system is a functioning, organized plan that furnishes for all areas those facts needed and wanted by administrators for effective operation of the institution. ..."
>
> "The total information system is a linked network of raw facts (data), processed data (information), the manual and automated procedures which make the network operative, and the organization that coordinates and operates the network, all of which are designed to aid in the operation of a college or university by providing the information needed at all administrative levels for control, evaluation and planning."

The ideas stated above can be summarized by saying that the only real solution to the informational problems associated with administrative activities is to implement a total design.

Capabilities and Uses of an Administrative Information System

A total design for a computerized administrative system must be structured around basic files in the data base. These files would contain sufficient detailed information on those items of information related to the administrative function.

The Henle Report [A 22] suggests the list of files given in Figure 3. The report elaborates on some of these files and defines their content to a detailed level. It takes up where this report leaves off, for it documents the next level of detail required to arrive at a field by field description of the files in the system.

In order to meaningfully use the data base, two major procedures are required: a maintenance procedure and a retrieval procedure. In other words, the files will have to be kept current and there must be a means of retrieving information to satisfy operational and special purpose requests.

Several innovative capabilities can be designed into a computerized system which handles and processes administrative information. These capabilities are documented throughout the literature and are presented in this document to demonstrate the tremendous power and usefulness of the total systems framework. The concepts to be discussed are:

1. Modeling and Simulation
2. Program Budgeting
3. Class Scheduling
4. On-line Access to the Data Base
5. Source Data Input
6. Interuniversity Communication

Modeling and Simulation. An important function of management is to plan for and to predict the future of their organization. Many of an administrator's decisions are related in one way or another to his prediction or image of what the organization will be at some future time. Intuition, rules of thumb and other heuristics have been used over the years to assist him in this process, but now the system parameters are too complex and do not lend themselves to this type of activity. Because of this, university management is turning to the use of computer models for predictive purposes.

There are many possible approaches to university model building. Some of the basically different approaches being taken at the present time are:

University of Toronto. A financially-oriented model known as CAMPUS in which ten-year projections could be made for future budget and staff requirements has been developed by Dr. Bertrand Hansen and his associates. In discussing CAMPUS, Mr. Pfeiffer in his book New Look at Education has this to say [A 35]:

> "The computer model may be regarded as a system made up of four sections involving enrollments, resources, budget and space. Information flows from one section to another according to rules specified in the programmed instructions. The basic input data, facts about the structure of the university and the number of students expected, are translated into department workloads in the model's enrollment section ... . This information in turn passes to the budget and space sections and is

> processed to yield essential output data concerning academic costs, administrative costs, general expenses and academic and administrative space requirements."

Michigan State. A computer-based model which deals with the problems of planning and resource allocation in educational institutions has been created by Dr. Herman E. Koenig and Dr. Martin G. Keeney.

In one of their reports, Koenig and Keeney state [25]:

> "The model is a mathematical description of the way the university utilizes its resources in production. The resources of the university are described, broadly, as personnel, space, and equipment. The products are identified as developed manpower, research and public or technical services."

Their model views the university as a total, dynamic, and interrelated system. The purpose of the model is to provide a rational basis for evaluating alternative allocation policies under the assumption that the university has varied and perhaps conflicting goals defined by those entrusted with decision making responsibilities.

University of California-Berkeley. John Keller, using the work of Charles Hitch, at the Department of Defense, has designed and implemented cost simulation models for the Berkeley and Los Angeles campuses. The models are similar to the program budgeting approaches now used by most government agencies.

The universities of Tulane, Cleveland, and Johns Hopkins are also performing various types of research into university model building. The approaches to date seem to be toward specialized models for particular institutions or particular systems within one university. However, some approaches have generalized aspects and hopefully the trend will be in this direction. In any case, by using models of their institutions, administrators are able to understand their institutions in deeper and more revealing ways.

Program Budgeting. Program budgeting is a philosophy of organizing financial information in such a manner that different courses of action (programs) can be analyzed individually in terms of cost and utility. It is implemented by organizing financial files around plans and objectives instead of around conventional or arbitrary categorizations. By its very nature program budgeting tends to cut across formal organizational lines. Because present design approaches are customarily organized along organizational lines, this method of financial accounting cannot be easily implemented in existing systems. However, the total systems design approach is a perfect vehicle for incorporating it into newly designed university accounting systems.

Class Scheduling. One of the problems which is still plaguing administrators in most educational systems is the scheduling of classes. The algorithms to quantitatively solve the problem exist and have been implemented on computers in many universities. The problem is, therefore, technically solved, but administratively it is still a headache for those who have no access to a computer or those who find it difficult to integrate scheduling systems into their existing administrative systems.

The problems associated with manual registration should be an activity of the past. The total system approach and its result (a total information system) could provide a means of combining the proposed class schedule with the students course requirements and could result in calculating a schedule which would best fit the interests of all concerned parties. In addition to the scheduling process, the computer could also perform other registration functions such as calculating fees and billing students. Since the student data base would be contained in the computer system, all the necessary information (such as out of state tuition information and information about assistantships and scholarships) can be accessed and used to compute each student's registration fee.

On-line Access to The Data Base. A total information system can be implemented with manual methods and procedures. "Total" implies that the design includes all components of the system and that the overall objectives are maximized over the entire system. However, even without a requirement for quick access to the data base, most extensive total system designs are structured around a computer. Even for periodic reports a computer is generally required for systems which have a large, dynamic data base.

Personnel files

- Vital data file
- Experience data file
- Cultural and educational data file
- Payroll file
- Current activity data file

Facility files

- Space inventory file
- Equipment inventory file
- Space use file
- Campus grounds file

Student files

- Student records file
- Vital data file
- Enrollment file
- Student activity data file

Resource acquisition files

- Appropriation file
- Industry income file
- Federal government income file
- Other income file

Expenditure files

- Payroll file
- Travel file
- Communications file
- Other accounting files

Program and activity files

- Course and curriculum file
- Research project and program file
- Short course and conference file
- Extensive activity file
- Graduate student supervision file
- Institutional service activity file
- Student service file
- Faculty service file
- Public service file
- Athletic program file
- Facility service file

Administrative Data Base Files

Figure 3

In addition to periodic reports there exists a requirement in administrative total information systems for some means of getting reasonably quick answers to certain types of questions. Some requirements for quick access to the data base are:

- *Ad hoc* queries during budget negotiations
- Crisis situations requiring access to summary data
- An open access to the data base for studies conducted by the Office of Institutional Research and by personal queries by the university president.
- Immediate means of checking for errors or inconsistencies in the data base.
- For use by guidance counselors and/or teachers when they are interviewing students.

This on-line requirement is, of course, secondary to the main requirement of a complete and comprehensive data base and a flexible means for obtaining required reports. However, an on-line adjunct to an off-line system is a necessary requirement when the total system is to provide information for administrative decisions.

Access to the terminals and to certain files in an on-line system would be restricted to certain offices or individuals. Special password should be required for the use of confidential files and a transaction log kept of their use. In a sophisticated on-line system, the on-line output might be in the form of charts or graphs and therefore require terminals with some kind of graphic capability. However, in most cases a teletypewriter would be the only type of terminal required.

Source Data Input. One of the primary reasons for using the total approach is to eliminate the unnecessary handling and transcription of information. The optimum systems design would provide for a minimal number of transfers or conversions of the data in the system. Source Data Input is a term which means that data is recorded into machine readable form at its point of creation and immediately supplied to the system. From that time on, only updates need be handled and there is no continuing necessity for large amounts of input to the system.

An example of the application of the source data input concept in an educational system is in the registration process. The registering student would be required to pencil-punch a special registration card which could then be directly read by a computer. Examples of other means of obtaining machine readable data are mark sensed or optically read registration forms.

Interuniversity Communication. The amount of information interchange between universities is increasing to the point that serious consideration should be given to interuniversity communication in designing a university's total information system. The interchange need not be of the on-line variety which would provide a direct means for one university to obtain information from the data base of another. However, on-line connections may be necessary for use with certain types of information, such as the library holdings and course offerings data bases.

The primary objectives are to facilitate information transfer among universities and to provide a certain amount of commonness in the university community in order to facilitate the orderly flow of information. A reasonable first step toward this goal would be the universal university acceptance of certain code systems used in the coding of university information. For example the social security number could be used by all universities as a student identification number. Universal agreement and use of the same coding systems would pave the way for more direct and on-line types of connections in the future.

The Conceptual Design of an Administrative Storage and Retrieval System.

The primary purpose of an administrative information system is to store and retrieve information useful to the university administrators. We have specified the general content of the files necessary to achieve these ends, but an overall design has not yet been presented. This section advances a conceptual design of a computer system to accomplish the overall storage and retrieval functions of administrative information.

The general design philosophy is to incorporate, as much as possible, into the design the means by which the system can be adapted to changing requirements. Historically, storage and retrieval systems have been designed to satisfy a particular need or to produce a particular series of reports. As the environment grows and new demands are placed on the system, the system, unless it has been so designed, is unable to satisfy these new requirements. New systems are created and the old one falls into disuse. The approach set forth in this section would minimize problems of this type, for the system would be able to produce, within limits, new reports or to be geared to process completely new files.

The system will be structured to satisfy two types of users - those who require periodic reports from the data base and those who require on-line immediate access to summary data. Therefore, in addition to the basic detailed files, there will be condensed, summary versions of these files on random access devices. The summary files will be created from the detailed files and will be used to answer on-line requests from those administrators who desire immediate answers to their ad hoc questions.

The types of questions which might be addressed to the summary files are:

- How many faculty members in the Math Department have been employed by the university for over five years?
- What percentage of the budget is currently being spent for research?
- What are the names and addresses of all faculty members who have attended universities in this state?
- What is the average grade-point ratio of undergraduate students in the Biology Department?
- What professors have speaking engagements this month?
- What are the titles of the current research projects in the Electrical Engineering Department?

The above questions are representative of the non-scheduled and unpredictable types which frequently arise. Their answers would give the administrator an insight into his data base and greatly assist him in his planning and evaluation role. An adequately designed on-line system could supply up-to-the-minute answers to these types of questions.

The detailed files would reside on sequential computer storage devices and would be used in the customary manner to produce standard or periodic reports.

These files would contain all the basic information required in the administrative system and need not be accessible on-line. Because of the hierarchical approach to the construction of the data base files, the detailed files will tend to contain disjoint information. This is desirable in order to reduce redundancy. However, there must be a means of relating the scattered pieces into a meaningful whole. This is possible by extensive cross referencing indicators in the records and by a programming procedure called multi-file retrieval.

Examples of reports which would be obtained from the detailed files are:

- Statistics and information for institutional research studies (e.g. student/teacher ratios by departments)
- Grant listings by donor, by financial status, etc.
- Payroll checks and reports
- Student grade reports

- Student grade reports

- Class rolls
- Student name lists by department, grades, home addresses, etc.
- Staff and faculty lists by department, position or academic rank, interest profiles, publications, etc.
- Summary information to be used for modeling and simulation
- Activity and Event reports

One way to incorporate into a system the flexibility of producing various output reports is to use a modular approach to designing the components of the programming system. Each basic function, such as searching for a particular record or totaling the numbers in a particular field across several records, should be written as an individual subroutine and a means provided to combine these into meaningful sequences to accomplish a particular task. Thus a task would be expressible in terms of these basic functions. As new functions (subroutines) are required, they can be defined in terms of old or new functions. This flexibility would allow the output of the system to be adapted to the changing administrative environment.

The file maintenance problem in a large and dynamic system of the type outlined above is highly complex. When a new file or even a new field in a record is added to this system, a means of maintaining the contents of that file or field has to be provided. Of course, all additions to the data base of the system imply that the new data must be collected and made available to the system. For example, if an activities file is to be added to the system, a means must exist outside of the computer system to gather and supply the initial information as well as any subsequent updating or changes to the computer.

The design of the maintenance system should make use of the same programs which are used by the retrieval system. The basic file handling functions, such as deleting a record, adding a field, etc. should be written as subroutines such that they can be easily combined in a meaningful sequence to perform a particular task. These basic functions or subroutines can be programmed and added at any time to the system. All maintenance and retrieval functions would be performed by connecting into a sequence the required subroutines.

Another aspect of maintenance is the upkeep of the summary files. These files are created and maintained from the detailed files. A procedure must be built into the system to provide for the automatic maintenance of an element of information (field) in the summary file whenever that field is updated in a detailed file. For example, a salary increase for one person posted in the detailed personnel file would create a change in every summary file which used information from that salary field. This is a complex maintenance problem, but can be solved ay an appropriate design approach.

A computer system based on the above concepts is designed to cope with the problems brought on by changing requirements, changing information, and changing interests. It would also provide two levels of service in that it would supply on-line summary data and off-line standard reports and would thereby service all the major administrative activities of a university.

Recommendations.

In order to provide a basis for future studies in the area of administrative information systems, a list of recommendations is combined in this section. Most of them are related to the eventual establishment of an environment in the university conducive to implementing a total design. The recommendations, though tersely stated, can be used by university administrators who appreciate the benefits and problems associated with total designs and who would like to know what steps they can take toward their eventual realization in their university.

1. Establish Information Systems Offices. This university office, which will eventually design and implement the information systems, can be formed from the present Office of Institutional Research (if one already exists). It is essential that this office be directly responsible to the president of the institution and that it have broad authority and scope in its activities.

2. Support The Total Systems Approach. The central theme of this report is total systems and it is viewed by the author as the best approach to alleviate many of the ills of the present piecemeal systems. This approach must be taken in any new systems design in the university environment.

3. Educate Administrators. Since the information systems presented in this section are for university administrators they must be expertly instructed in its design principles and in its use. This can be done by holding conferences or by offering short classes on the major concepts, on the costs involved and on the advantages of the approach.

4. Encourage Interuniversity Communication. Several national groups, like EDUCOM, which have as their objective the fostering of better interuniversity communication. Their work should be encouraged, supported, and extended.

5. Establish an Information Systems Clearinghouse for Reports. The more work performed and documented on university information systems, the more it is necessary to establish a national clearinghouse where the reports can be disseminated to interested parties. There exists no such organization at the present time. The approaches and work in one university may very well be useful in another and a national organization can provide the necessary communication channels.

6. Encourage More Information Systems Research. The programming and systems techniques to implement what has been discussed in this report are not all solved. There are still some technical problems whose solution would improve the effectiveness of the total approach. This is certainly true of total information systems. However, the day has arrived when the computer can be used as it should in assisting man in processing his increasing volume of university oriented information.

Most of these recommendations are for action at the individual university level. However, some of them require a national organization for coordinating and studying the problems and the promises of university information systems. Such an organization has been proposed. The following is an excerpt from a draft copy of a proposal to create such a national organization [A37]:

> "Associated Universities, Inc. a management organization sponsored by nine universities proposes to establish a national institute, to be called the NATIONAL INSTITUTE FOR UNIVERSITY INFORMATION SYSTEMS, whose purposes will be to conduct research and development, education and information dissemination activities, and test and demonstration operations with computer-based systems for research, instruction, and administration in higher educational institutions."

The support of this type of national organization and the establishment of a systems group within each university are two important first steps in a total approach to university information systems.

TEACHER INFORMATION SYSTEMS

Introduction.

The objective of this section is to discuss information systems which can be used to increase the effectiveness of university teachers in the performance of their duties. The systems presented are oriented to the many different but related functions performed by a teacher. In addition to the information systems, general background topics are discussed and related to teaching. After the introductory comments, the section is developed as follows: an enumeration and discussion of the various functions of a teacher, the data bases used in the teaching process, and a systematic development of information systems oriented around each function of the university teacher. The section concludes with a list of recommendations which summarize the important ideas contained in it.

A distinction is made between the functions of a teacher and those of instructor. A teacher is that member of a university faculty who strives to make the students more effective, productive, and creative members of society. Instruction is one of several important tasks of a teacher and is that task which is performed by a teacher in the classroom or with an individual student when he is communicating substantive information. Therefore instruction and teaching, are not used synonymously in this paper.

The job of a university teacher requires that he communicate with his students. However, the test of a good teacher is not simply his ability to communicate in the classroom environment, but also his ability to organize courses, to make decisions on what to present to his class, to select the appropriate teaching aid and methods of presentation, to tutor those students who require extra attention, and in general to guide the student in his quest for knowledge. To accomplish these objectives is no easy task.

The word "teacher" is not easy to define. The dictionary offers the incomplete definition - "one who instructs." A larger, more encompassing definition is required to describe the total activity which culminates in the instruction process. A teacher usually spends a small percentage of his time in classroom instruction; the remainder is shared between activities in preparation for this instruction and activities related to tutoring his students.

We also note that no two teachers seem to approach their profession in exactly the same way. Some teachers seldom prepare for a class lecture, while others spend hours in searching for the most effective way of presenting a particular topic and seem to be never satisfied that they have found the "right" way. This section is written for any teacher who is interested in the information systems which will assist him in becoming a more effective teacher.

The teacher is above all an information processor, for he deals solely with information. His entire job is centered around information about students, subjects, methods, concepts, current events, policies, and many other topics. He is called upon to store, manage and reproduce this information in such a way as to effectively reach and teach the students in his classes. He requires different types of information systems which are not only responsive to his needs today, but are adaptive to what his needs may be tomorrow.

The design of information systems for teachers is approached from a functional viewpoint in this paper. Individual information systems can be constructed which support the teacher in each of his major functions. In certain instances some of these information subsystems could be combined, but they are presented as separate systems for emphasis and simplicity.

The university environment has within it the conditions and situations which have a varying influence on the professional attitudes and development of its teachers. The occupational hazard of laziness, the pressure to conduct research, the trend toward mass instruction, and many other related demands and pressures placed on a teacher tend to divert him from his primary objective. The full-time teacher, on the other hand, is able to devote his complete attention to the crucial mission of the university - to educate its students in the most effective manner possible.

College and university teaching environment is in many ways unlike the corresponding environment in high school. The student is generally more highly motivated and scholastically disciplined when he reaches the university. High school teachers spend much of their time on peripheral matters and have only a small amount of time to scholastically motivate the student. In universities, these extraneous activities are generally not required and the university teacher can devote his full attention to presenting the subject matter in a useful and challenging way. He is greatly assisted in this job by the student's own motivation which is much stronger than in high school because of the rewards society has placed on university achievement.

Another difference between university teaching and high school teaching is the area of concept teaching vs fact teaching. By the time a student enters a university, he is equipped with a large repertoire of facts. One of the tasks of university teaching is to place these facts in proper perspective. Additionally, the university teacher will add more facts and teach concepts which will equip the student to become a useful member of society and to be proficient in his particular field. In many university courses, the primary emphasis is on concept learning and the secondary emphasis on fact learning. The information systems discussed in this section are designed for all types of university teachers, but especially for those who emphasize concept learning in their courses.

The subjects of programmed instruction, teaching machines, and computer assisted instruction are currently being studied by a great many people and are being applied to the university instructional system. There is little doubt in the author's mind that these methods are of value in presenting certain subjects to certain types of students. They can be worked into the instructional process and are one of many methods used by a teacher in an instructional information system. This paper will not describe these approaches, but will demonstrate how some of them might be effectively used in certain teaching information systems.

Functions of a Teacher.

As one thinks in greater and greater detail about what functions a teacher actually performs, he realizes that many of them are in some way related to instruction. It must be emphasized however, that a teacher's "performance" in front of his class is the end product of a sequence of preliminary and important tasks which, if not done properly, seriously hinder the effectiveness of his instruction. Therefore, a functional analysis of a teacher's activities forms a reasonable basis for a study of his information systems.

The functions of a university teacher which are discussed in this paper are:

Course Design and Revision
Pre-instruction
Classroom Instruction
Testing and Grading
Tutoring
Computation
Composition

Course Design and Revision.

The information explosion and the increased student and social demands have placed pressure on the university for relevancy in the curriculum. Teachers, in turn, are pressed to incorporate an up-to-dateness in their courses. Of course, some subjects and some teachers are affected more than others, but the overall picture is clear: many university courses today are undergoing a metamorphosis and the topics being covered are becoming more relevant to social needs and industry demands.

Because of the expanding technological base, new courses are constantly being added to universities' curriculums. In fact, new interdisciplinary departments are becoming more the rule than the exception. The teacher is at the crux of this renaissance, for in many universities he is responsible for designing, revising, implementing the courses which he teaches. In the final analysis, it is the teacher who must perform the research, check for allied courses, consult with his fellow teachers, and combine all worthwhile ideas into new or revised courses.

In the years ahead university teachers will be increasingly called upon to perform the function of course design and revision. In this context it should be noted that the better a teacher incorporates the underlying topics in the design of a course, the less apt it is to require revision later. Some teachers find revision difficult; others have always considered it a necessary part of their jobs. The information systems advanced in this section are useful to any teacher who has to perform this design and revision function.

Pre-instruction

Instruction can be considered a process; that is, it involves more than one function performed in a meaningful sequence. In order to discuss instruction more meaningfully, it is divided into two functions: Pre-instruction and Classroom Instruction. Pre-instruction is preparatory to classroom instruction and begins for the teacher after the course's content has been determined. It includes all the preliminary activities which a teacher performs before he actually walks into the classroom.

Some of the activities required for the function of pre-instruction are: selection of teaching method for each concept, determination of which presentation aids will be appropriate, preparation of class notes and supporting material, and review of material just prior to the class period. A review of relevant teaching methods and presentation can be found in the Teacher Information System Bibliography at the end of the paper.

Consider the following pre-instruction activities. To teach the concept of "relation" in a mathematics course, a teacher may decide that the lecture method would be best to maximize the student's learning experience. He could prepare graphic examples of relations for use on the overhead projector, select homework problems, and possibly recommend a programmed instruction text for use by those students requiring additional material. These activities are culminated in the next function.

Classroom Instruction.

All the actual classroom activities and the private instruction of the teacher are included in this function. Since the teacher controls the classroom environment, the communications between the teacher and student as well as the student comments are also considered part of this function.

It is interesting to note that a well executed pre-instruction function does much to enhance the actual classroom instruction. It is necessary, but not sufficient to produce a meaningful classroom learning experience for the students. Many well planned lectures have been sacrificed by an instructor who muted his voice by talking to the blackborad or one who lulled his class to sleep speaking in monotones.

Some say that the classroom behavior of a university teacher requires a slight theatrical orientation, but only enough to keep the students interested in the content, not the form of the presentation. A teacher's well delivered lecture may win an award for oratory, but may not be comprehensible to the majority of students in his class. The objective in this function is to capitalize on every possible approach in presenting the course material in order to maximize the student's learning experience. We will, therefore, be student oriented rather than teacher oriented in our approach.

Testing and Grading.

Every teacher is required to test his students in some way and to assign a grade to each. Right or wrong most university teachers are permitted to perform this function with few, if any constraints. Unfortunately, there are few standards and no universally accepted correct way to test and grade students. It is truly one of a teacher's most arduous tasks and one which is viewed by many as urgently in need of some type of support.

Most universities require that a grade be assigned to each course that a student takes. The standard procedure for arriving at a grade is for the teacher to administer tests, correct them, compute an overall average, and use this average as an indicator or measure of what the student has retained in a particular course. Frequently subjective opinions of the student are used to temper the final grade.

The importance attributed to testing by teachers is many times not consistent with the importance placed on the student's grades by society. For example, the content and orientation of the tests in a course may not be representative of the material covered. Also the relative weighting of test answers may be different from the relative emphasis placed on the topic in the classroom. The randomness which is inherent in spot testing and the variations in grading philosophy among teachers are historical weak points in our testing and grading system. Many concerned teachers are trying new approaches to testing and grading and with better information systems this function may some day be more effectively performed.

Tutoring.

A university teacher is frequently called upon to tutor or instruct his students on an individual basis. This function can take a variety of forms - from reviewing a concept covered in class to recommending subsequent course work. It is sometimes helpful for the teacher to prepare for this meeting with his student by reviewing background information on the student. For example, if the student has an obvious interest in a particular area, it may be helpful to use examples from that area to illustrate an unclear concept.

In most universities, there is no existing system which can supply immediate background information on a student. Even if the appropriate information is recorded in the registrar's office or in the departmental office, it is usually difficult to obtain it on a continuing basis. This function could be significantly improved for both the teacher and student if an information system existed which could supply the necessary student background information immediately upon request and with little or no inconvenience experienced by the teacher or the student.

Computation.

A teacher's job frequently requires him to have access to a calculator or a computer in order to perform lengthy computations. In teaching a mathematically oriented subject, numerical calculations are frequently in order. It is a waste of time for the teacher to laboriously carry out computations when this function could be performed more cheaply and accurately on a machine.

Desk calculators are sufficient for many types of arithmetical computations, but more sophisticated equipment is required in order to perform complex calculating. A teacher who teaches a subject in which computations are required of the student, should have on-line access to some kind of machine. For example, a remote time-shared terminal in an engineering teacher's office may free the teacher for more creative work.

Composition

In order to adequately perform other important functions, a teacher is required to document his thoughts. This activity of writing or composition when summed over many activities can result in consuming a large percentage of a teacher's time. For example, the writing of a course syllabus, the describing of an experiment, the listing of homework questions, and the preparing of a bibliography are all activities which require the teacher to translate his thoughts into written form.

At present most university teachers perform this activity by writing a draft copy, getting it typed and duplicated, and distributing it to their class. Some teachers are now using dictation equipment in an effort to save time and reduce overall costs.

The Teacher Data Bases.

A teacher constantly refers to information stores or data bases as he performs his many functions. On a daily basis he uses a textbook or his lecture notes. Less frequently he must reference information from the library or his own files to support his teaching mission. And periodically he requires administrative information concerning his students. The extent that these data bases are used depends on the particular teacher. A teacher who attempts to keep his courses current will naturally use the reference data bases more than a teacher who does not. The administrative and the scientific (library) data bases are also discussed in the other sections of this paper.

Administrative Data Base.

All the information about the student is stored in the administrative data base. Currently the major uses of this data base are for printing class rolls and for storing student grades. This data base could easily be used to supply summary background information about the student to the teacher. The internal organization of this data base need not be complex. In fact, only one file is required for the teacher's use and he should have on-line access to selected portions of this file. He could retrieve information from this file for tutoring and send student grade information to the file. The basic types of information in the student file are listed on Figure 4.

The Concept Data Base.

Another data base is required to handle the concept teaching philosophy discussed in this section. This data base, called the Concept Data Base, contains information about each of the major concepts taught in the university. In most university systems which exist today this data base, if it exists at all, is stored in the files of the teachers who use a concept approach in the presentation of their course material.

The individual concepts in the Concept Data Base are initially established at a departmental level. This is required because most concepts would be oriented to a particular discipline. In a manual information system this data base could be handled simply as a hard copy file in which a folder in the file would represent a single concept. For instance, in the computer science department, the following would be examples of some concepts, each of which would be stored as a single record or in a single folder in the file:

- Recursion
- Number Systems
- Error Detection
- Random Access

Categories of Information

1. Student Identification
    - Name
    - ID Number
    - Class
    - Enrollment Year
    - ⋮

2. Location Information
    - Home Address
    - Dormitory Room Number
    - ⋮

3. Background Information
    - High School Courses
    - Military Service
    - ⋮

4. Scholastic Information
    - Scores on Standard Entrance Tests
    - Courses and Grades
    - ⋮

5. Non-Scholastic Information
    - Scholarship or Assistantships
    - Organization Memberships
    - Outside Employment
    - ⋮

6. Financial Information
    - Current Fees
    - Past Payments
    - Loan Information
    - ⋮

7. Other Information
    - Interests and Hobbies
    - Special Talents

Contents of Student File

Figure 4

- Time-Sharing
- Associative Memory
- Modular Programming
- Polish Notation
- Subroutine Linkages

Several categories of explanatory and supporting information needs to be associated with each concept. The following is a list which gives the major types of information required for each concept:

- Concept name
- Alternative names
- Abstract of the concept
- Alternative descriptions of the concept
- Methods of presentation
- Useful instruction aids
- Questions related to the concept
- Bibliographic references
- Cross reference to supporting information
- Class notes from teachers who have presented this concept.

A concept file containing the information given above would be a great aid to a teacher at several stages in his teaching role - course design, instruction, testing. With such a file, a teacher would be able to build on the past more effectively rather than to recreate everything anew each time he is required to teach a course which he has not previously taught.

Information Systems for University Teachers.

In this section a number of systems in which information can be more easily handled and processed for university teachers are presented. They are collectively called teaching information systems, for information is the essential ingredient or the key factor under consideration in each of them. The information systems are aligned to each of the major functions of a university teacher and therefore the development parallels the previous section on Functions of a Teacher.

The external information systems were of prime interest to the author and are the only ones discussed. The process of selection, evaluation, and communication which is performed internal to the teacher and the process of learning which is performed internal to the student are extensive research topics in themselves and were not included in this project.

The primary objective behind each of the information systems presented herein is to assist the teacher in upgrading the quality of instruction and thereby increasing the student's learning experience. The quality of instruction can sometimes be indirectly increased by relieving the teacher of automatic, time-consuming tasks. It is for this reason that some information systems are suggested which primarily reduce the time spent on some of the lengthy automatic jobs associated with teaching. With this additional free time, the teacher can concentrate on other more meaningful tasks. The majority of the information systems which are presented, however, directly help the quality of instruction and usually result in additional time too.

Within each type of information system, the proposed suggestions are discussed in a natural implementation or chronological order. That is, the manual, easily implemented information systems are given first, and from this base, more complex systems are constructed. In most cases, the final approach is a highly computerized system involving remote terminals in the offices of the teachers.

There is an obvious interface between the administrative information system and the teaching information system. These systems are connected in the organization by the department head. He is an administrator and at the same time is the director of the teaching mission of his department. He is concerned with summary information on overall course content and generally leaves the details of the courses to his teachers. His major interests center around curriculum planning and scheduling, general administrative tasks, and coordination activities. All of these functions are supported by the administrative data base and are outside of the actual teaching information systems discussed in this section.

Course Design/Revision Information Systems

It is becoming more and more imperative for university teachers to incorporate up-to-date concepts and a higher degree of relevancy in their courses. This is especially true for rapidly changing technological disciplines and for courses which are related to the world's ever changing social, economic and political environment. This reduces to a requirement for teachers to either design new courses or revise old ones. What type of information system can be used to most effectively assist the teacher in this activity? Several different approaches to answering this question are now presented.

The necessity for feedback from the students is critical in a student-teacher relationship. The course critique administered at the end of a course is probably the most important vehicle by which the student can express his impressions of the course as a whole. It is usually administered before the final grades are posted and can be designed to get the student's view of the importance of various concepts. Of course, a student's opinion on course content is tempered by a number of factors and is not always a valid indicator of actual importance. However, it can at least be considered a weak indicator and is better than none at all. The results of the critique can be used, say on a statistical basis, to point out those concepts which for some reason do not rate high with the students. Appropriate action can then be taken in the form of either revising the content of the teaching method for that portion of the course or obtaining more detailed results from the critique of a future class.

If a course is designed around concepts and their explication, then the concept data base might be periodically reviewed by the teacher for additional information. This data base, whether it is kept at a department or university level, could also be used in the design of new courses. A comparison of the concepts in the concept data base with the concepts currently taught in the courses would show which ones are missing from the curriculum. Appropriate action could then be taken to close the concept gap.

In designing or revising a course, it is frequently of interest to know those courses in the university curriculum which are prerequisite, corequisite, postrequisite, or which partially cover the same material. An information system could be constructed using as a data base the description of courses given in the university catalog. For example, the catalog description of each course could be key punched and stored in a computer. A retrieval system could be designed which would use these descriptions as abstracts. To use this system, a teacher would first list those concepts he is interested in. These concepts would be used as keywords which would be matched with all the abstracts (course descriptions) already stored. All relevant courses would be listed as output. The course dependences obtained by using this system would greatly assist the teacher in his designing and revising role.

If a teacher is considering presenting new topics to his class, he is usually interested in reviewing the cumulative literature related to the topic. If little or no information can be found in his personal files, he usually visits the library. The normal procedure in the library is to manually check the card catalog, search through the stacks, and check out those books found. A more sophisticated approach to this activity would involve maintaining subject and concept bibliographic files on a computer. Using an appropriately designed computer system, the teacher could obtain complete bibliographic lists of books, articles, and reports pertaining to his request parameters. A KWIC (key word in context) system using titles only would be a first step in the implementation of such a system. Later versions could use abstracts of each article. This type of information system could be the on-line component of the off-line information system discussed in the next paragraph.

A further computerized approach to keeping the teacher informed is an information system for automatic dissemination of references or abstracts of all current documents which match a teacher's interest profile. A university information center could be set up and its staff required to screen all pertinent documents related to the subjects taught at the university. This screening process would result in an index or abstract of each document which would subsequently be stored in the computer. The teachers (and other staff members) would represent their interest areas or profiles in a keyword form and this information would also be stored in the computer. Periodically the teacher profiles would be matched against the new abstracts and the individualized results sent directly to each teacher. A teacher would therefore be automatically notified of those documents in the literature which relate to his field. Using this as the primary source of information, he can keep the content of his courses up-to-date.

Pre-instruction Information Systems.

In using information systems in this phase of the instruction process the teacher is primarily interested in the selection of a particular presentation method or the use of an instructional aid to assist in the presentation. The material to be presented has already been established and at this stage we are only interested in the form and manner of presentation.

Since many instructors have not been trained in the use of teaching aids, they should be required to attend a course in presentation methods and instruction aids. In addition, they should have an up-to-date reference manual on the most effective teaching aids for concepts germane to their discipline. This manual should be general enough to cover all aspects of university teaching, but specific enough for actual use by any university teacher. This type of information system (i.e. an actual course) should be taught as an example of good instruction.

For those teachers not interested in a course on how to teach, a programmed instruction manual could be designed and written which would allow them to learn the basics about teaching methods and aids. A teacher with 25 years experience need not be embarrassed by taking a formal course on topics which he is supposed to already know. But he can still take advantage of improvements and innovations in this important field by studying them in programmed instruction form.

Classroom Instruction Information System.

In the classroom, the instructor has a number of information systems which he can use. In fact, he need not be present in person at all, for he could video-tape his lecture in advance and have it shown at the regular class period. In certain types of lecture-oriented courses, this may be a useful and effective method. The teacher would then have more time available to his students for clarification or discussion of the concepts covered in the taped lecture. When the instructor has refined his lecture to a sufficient point, he may then have it filmed and permanently stored. The video-tape or the film could be made available at any time to the student for replay on an individual or group basis. This method is sometimes criticized because of its depersonalized nature. This is, frequently, not a criticism of the method, but the way it is used in a particular situation.

Most instructors who are sensitive to the feeling and mood of their classes have subtle means of obtaining an immediate feedback from the students concerning how well they are receiving a new topic. An experienced instructor can get an indication of student comprehension by facial expressions, the amount of note taking activity, the number and content of questions, and the general attitude of the class. Feedback insensitive instructors forge into new material before sufficiently covering introductory or prerequisite material. This type of instructor requires a more obvious communication link with his students.

One means of getting immediate feedback from students is a classroom feedback system which utilizes electrical connections between the student desks and the instructor's lecturn. On each desk is a button or a series of buttons through which a student could relay his reaction to what is being presented. On the instructor's lecturn a read out device indicates the overall student reaction. With a multiple button system, the instructor can get a measure of the following feedback information from the students: "Going too slow"; "Going too fast"; "Give an example"; "I can't hear you"; etc. The advantages of such a system are primarily related to immediate reaction to the current instruction. The disadvantages are centered around possible student abuses. As in any system of this sort, it could always be turned off by the uninterested or annoyed instructor.

In many courses, the computer could be effectively used during the classroom presentation. Using a remote terminal in the classroom, the instructor could have the computer perform on-line computations or retrievals and have the results displayed on a cathode ray tube, on a screen, on a graphic device such as a plotter, or in audio form. Given adequate preparation and interface langauges, an imaginative instructor could demonstrate many types of course material in a rather dramatic fashion.

On-line simulation is a prime candidate for classroom use of a computer. With the help of the computer and adequate preparation by the instructor, the students can experience a live simulation process which unravels step by step. This type of dramatic use of computers would tend to heighten the student's learning experience as well as explicate complex concepts. Any course in which models can be used to explain concepts would be a possible candidate for classroom simulation.

Another extensive area for computer use in the classroom is computer assisted instruction. If used effectively,CAI systems can be interwoven into the instructional program to "teach" those courses or concepts which lend themselves to present CAI techniques and devices. We call attention to the tremendous potential that programmed instruction in all its various forms has for university use, but we will not pursue the use of these systems in any detail in this report.

Testing and Grading Information System.

This is probably the most critical activity in which teachers need immediate support. However, information systems to support this activity are virtually nonexistent, for most of the required information does not exist in easily packaged form. As we discussed earlier, tests are frequently constructed and graded in a less than perfect manner. Also the final grades may be quite subjective and vary considerably in distribution from teacher to teacher - even those teaching the same numbered course.

Since society places such a premium on grades, the university should have appropriate means of insuring that they accurately measure what they are supposed to. In most cases the grade is supposed to be a measure of the amount of information a student has absorbed from a course. This measurement is historically done using tests containing sample questions which are suppose to be representative of the course material.

Since one problem with testing and grading is the fact that it is an individualized activity, some overall improvement is provided by departmental tests. Unfortunately, this standardization brings with it a type of regimentation that may produce enough negative effects to overshadow the positive benefits.

Another problem with testing is that of what to test. The unanswered question is: what should a university teacher test? Some possibilities are: short term retention of facts and concepts, long term retention of facts and concepts, an ability to apply facts to a new situation, problem solving ability, creative ability, expressiveness ability, computational ability, etc. Standards must be established for each course in order to document exactly what type or types of memory, application or ability is to be tested. Then texts can be constructed towards those ends. A basic information system to support testing might consist of a teacher's file of old test questions, each of which has been indexed by a term which describes what the question was testing and the performance on this question by previous classes. Using this file, a teacher could continually perfect his test questions from a history of previous performances.

The adequate grading of a subjective test is extremely difficult. Much depends on what the teacher reads into the student's answer. Objective tests, on the other hand, yield an absolute numerical grade. For this reason many teachers prefer the objective type. Once a final grade is determined for each student, it can be posted in the student's file directly from the teacher's terminal. This would eliminate a number of transcription steps which are inherent in present procedures.

Tutoring Information Systems.

The major problem in existing systems of this type is the lack of information about the student's background. When a teacher assists a student privately, he usually knows little more than the student's name and his general performance in his class. Moreover, a short conversation with the student may not expose enough additional information on which to base a meaningful discussion directly tailored to the student's particular problem. The presence of appropriate information about the background of the student would be helpful in reducing the teacher's time with the student, while at the same time increasing the value of the encounter for the student.

One manual information system which is already used by many teachers is the student profile. On the first day of class, the student is required to fill out a short questionnaire on which he gives appropriate background information. This data base can subsequently be used by the teacher for a number of purposes. Foremost among them is a source of pertinent facts about a student which would be useful in preparing for a tutorial session. Each teacher would be responsible for designing the questionnaire in such a manner as to obtain the critical background information which relates to his course.

A computerized extension to this idea is an on-line terminal connectable to the Administrative Data Base. In this data base a single copy of the complete background of each student would be stored. A teacher could refer to that information in the student file which he would need in preparing for a meeting with a student. He could use the on-line terminal in his office for this activity.

The first tutorial session may result in a need for more intensive remedial or supplemental work. Instead of taking up large amounts of a teacher's time, the teacher could refer the student to specific programmed instruction texts, video tape or filmed concept presentation or some other passive type of instruction. After this outside assignment has been completed, the student can again meet with the teacher at which time the teacher would insure that the student has been properly and sufficiently helped.

Computational Information System.

In many teaching disciplines there exists a requirement to perform involved numerical calculations. A teacher who is relieved of such time-consuming tasks is freed to perform more creative work. For occasional straight arithmetical computations a desk calculator is hard to beat in terms of cost and ease of use. As the computations get more frequent and more complex, this system should be converted into one which uses a remote terminal connected to a computer. Not only can more involved work be done faster, but additional computational capabilities can also be realized.

There is a growing use of models and simulations in many non-mathematical fields. For example, many business and management courses are structured around the use of models of the firm and simulations based on these models. Because of the number and the complexity of the mathematical computations in simulations, the computer is used extensively. A remote terminal connected to a computer system capable of performing various types of simulation is not only an aid, but a necessity for a growing number of teachers.

Student homework assignments in a few years will require that the student have on-line access to a computer. The on-line terminal may resemble a conventional telephone and be used either in a central location like the library or in a student's dormitory room. The teacher will need to use his terminal to formulate the homework problems and to monitor the progress of each student by periodically asking for status information from the computer's record keeping programs.

Composition and Reference Information System.

The final output from many of the activities of a teacher is a written document. There are several information systems which can help the teacher in this composition function. The ultimate user of this information is usually the student, so the more complete the exposition, the better it usually is for the students.

We first draw a distinction between creation and maintenance of teacher-related documents. The creation process is quite subjective and few systems exist which can produce any sizeable benefits. Possible time saving devices are dictating equipment to replace handwritten copy and a well designed cross-indexed manual filing system for fast access of course related material.

The maintenance of information once it has been edited requires different considerations. One popular information system for keeping syllabi and other course information up-to-date is built around a typewriter/magnetic tape device. Information is stored on two small (3" x 3") magnetic tapes attached to a special typewriter. Information is read from the first, modified, and written on the second.

This information system can be used as follows. A course syllabus is typewritten onto a tape. (This tape is then considered the master tape). A modification to a course could be inserted easily onto a new master tape by using the old master tape as input. The next time the course is taught, the up-dated version can be automatically typed onto a mimeograph master and student copies made from it. In using this system there is never a need to retype the entire syllabus after the creation of the firstmaster tape.

More capabilities are obtainable from a computerized approach to the maintenance of teacher records. There are several computer-based systems in use in business environments which give the user an extended capability in composing, editing, and maintaining files of stored information. In a large university, the efficiencies gained with the use of this type of system might make it a reasonable evolutionary step beyond the typewriter/magnetic tape approach.

The Total Design of a Teacher Information System.

Because of a teacher's wide span of functions, it is difficult to envisage a single, neatly defined total information system which would satisfy all his information processing needs. We must first, therefore, consider a total design of an information system which would use the processing power of a computer and new software (Programing) techniques selectively to assist the teacher in as many ways as possible. With this in mind we can, in the following paragraphs, talk about the individual parts of a system which are designed as a totality from inter-related parts.

One of the underlying bases for using any sophisticated computer system is the type of programming needed to support the various information processing needs of the teacher. Another is the capability to use these programs from remote terminals. It happens that both of these are software features and that the presence of one does not imply the presence of the other. We can therefore conclude that the Teacher Information System or any of the other total systems discussed in this paper are not possible without a tremendous design and programming effort.

There should be a versatile terminal device in the teacher's office (or close by) and other types in the classroom. The office terminal may range in complexity from a touch tone telephone to a cathode ray tube (CRT). The terminal for use in class presentations is primarily for display purposes and would probably be specially designed for that purpose. They should not, however, be disjoint in the capabilities they provide, since the teacher may want to "debug" a class presentation from his office terminal.

In the confines of his own office, the teacher will want to use his terminal in a number of different ways. Four major types of user programs to support his needs can be identified. They are:

- Information Search
- Numerical or Logical Calculations
- Simulation Programs
- Composition and Documentation

The interface language between the teacher and computer should be easy to use, and he should have the capability of saving intermediate results, of easily going from one functional use of the computer to another, and he should be able to write, debug, and execute his own programs from his terminal. If his terminal can only handle low volume input and output, there should be a half day turnaround mail service between the computer room and his office for two-way high volume information exchange.

One type of terminal in the classroom should be for use in presenting demonstrations and simulations to the class. Its interface language would be the same as that used in the teacher's office, but the output options would be more extensive. A second type of terminal should be for the student's individual use and should be primarily designed for computer-assisted instruction and similar techniques. He should have some computation capability through it but the options provided him should not be as extensive as that provided the teacher. For example, the student should not be allowed to access any administrative information.

In addition to the programming support, a number of data bases are required for use by the teacher. The major ones discussed in this report are the:

- Student Data Base,
- Concept Data Base,
- Curriculum Data Base and
- Library Data Base.

Information transfer between these data bases and the teacher must become an easy activity for any total information to be successful. Ease of operation is, in many cases, that aspect of a system which must be achieved before acceptance will be possible.

Recommendations.

The following list of recommendations is intended as immediate steps for those teachers and administrators who desire to incorporate more effective information systems into the teaching mission of the university. This list also represents a summary of the more pertinent comments made in this section of the report.

Establishment of a University-wide Information Center.

An information center is a critical need in most universities. It could be set up to perform a number of information-based functions; however, its primary job is to screen the general literature and to disseminate selective information in the form of citations or abstracts to appropriate university staff members. These activities could be begun at the department level (and are already performed by many departments) and gradually upgraded, combined and merged into one center at the university level. In multi-level university systems, this type of activity might be performed most efficiently at the highest administrative level. (e.g. State coordinated University Systems).

Other functions of the Information Center could be:

- preparation of faculty-staff newsletter
- preparation and coordination of news releases and information pamphlets
- handle all press-release and public-related information
- administer courses on teaching methods and aids
- handle orientation for new students and staff.

Establish an Adequate Student Feedback System.

An efficient instruction process requires some type of immediate feedback information from the student. At present the feedback from classroom comments and from tests is the only means by which the teacher-student-teacher communication cycle is completed. Two suggestions are advanced in this paper to improve the amount and timing of feedback to the teacher. First, some type of electronic connection between the student's desk and the instructor's lectern should be designed so that the students may register their immediate classroom reactions. The instructor could determine the mood of his class immediately by asking questions and observing the collective response on his control panel.

Secondly, many people feel that since the students are graded, the instructor should be also. It is certainly true that most university students are not qualified to judge the quality or content of the material presented to them, but they can give their opinions on whether the manner or form of presentation was adequate enough for their learning experience. There should exist some formal and required type of student critique for each course, so designed that it can aid the teacher in a revision of the course or at least in the manner in which the material is presented.

Establish a Methods and Aids Training Program.

It is a common belief that an advanced degree automatically makes its holder qualified to teach at the university level. In a certain sense this is valid - at least in the sense of being knowledgeable in a substantive area. However, few university teachers have taken courses in public speaking, teaching methods, and presentation aids and many teachers who have a complete and extensive command of their subject literally strike out in the communicating or instructing process in the classroom. The situation is analogous to training an athlete to the peak of condition, then making him play a game without first informing him of the rules.

Conscientious teachers make it their business to find out all they can about ways of presenting information to their class. However, some teachers require prodding by their superiors. This encouragement should take the form of requiring teachers to take an occasional short course on instruction methods and presentation aids. Registration for these courses should be based on department standards and the results from student critiques.

A methods and aids training program should be established at the university level to construct, teach, and encourage participation in the Effective Teaching short course. The department responsible for the program could also be responsible for supplies and equipment which can be used by the teachers in implementing the approaches covered in the short course. This type of program should be included in the information center discussed earlier.

Establish Computer Software Support for Office Terminals.

There is an increasing need for teachers to have a direct connection with the capabilities provided by a computer. This direct connection in the teacher's office can be in the form of a typewriter-type terminal which can be connected to a computer over the regular telephone lines. This type of system is currently provided only to a few teachers who primarily use it for computational assistance. The information systems discussed in this paper are designed to use the terminal-computer system in a much greater and potentially more rewarding fashion.

The critical component in this type of system is the software support for the computer itself. The communications component is well within current technology and many manufacturers could readily supply the remote terminals and the central computer. However, the computer programs which are required in many of the teacher information systems discussed are not easily integrated into one overall system. Most of them exist as separate programs, but their integration and transition to a time-sharing environment is a non-trivial job.

A gradual implementation plan would probably be best for a university. A few terminals for numerical work is a reasonable beginning. Then, as more information retrieval programs are added to the system, more teacher terminals can be added. As a goal, every teacher should have easy access to a terminal and an extensive variety of software to support his many functions in and out of the classroom.

Concept Data Base.

The previous section on The Concept Data Base briefly discusses the creation of a new type of data base for teachers. It is a data base which is oriented around the major ideas or concepts which are taught in the university. Concepts are the building blocks on which many of the university courses are constructed. In a sense, they form a bridge between the world of facts and the world of applications.

It is recommended that an analysis be made on the concepts taught by a university - first at the teacher level, then by department, then at the university level. After this is performed, the concepts should be synthesized into a data base which contains a record for each concept. The data base could then be used as described in this paper. By constructing and continually updating this type of a file, a first step toward a useful data base for teachers can be taken.

RESEARCH INFORMATION SYSTEMS

Introduction.

The objective of this section is to define the functions of a researcher in the university environment and to discuss the information systems which he can use to help him meet his objectives. The approach is similar to that used in the section on Teacher Information Systems, and since many of the functions of the researcher are the same as those of the teacher an occasional reference will be made to the discussions in that section.

One of the major objectives of a university is to perform basic and applied research into those areas defined by the competence of its research staff. Historically, basic research has always been carried on in the universities, but applied research is gaining a foothold. It does not make a great deal of difference what type of research is being performed for the information systems which support either of the activities are not usually dependent on the type. Therefore a sharp distinction between basic and applied research need not be made in this paper.

The reader will observe that the total approach discussed in the section on Administrative Information Systems is used in a modified way in this section. However, the setting has changed from considering the entire administrative system to the information systems used by an indivdual researcher. Thus we will look at a researcher and his information systems as we did the teacher and his information systems. "Total" in this context applies to the total information related activities or functions of a typical researcher.

Functions of a Researcher.

An analysis of the functions of a university researcher results in a description of a number of activities which he somehow meshes together to achieve his objectives. Taking the functions individually, one might conclude that they really characterize the activities of any person who has a data base and is required to put a report together which somehow uses the information contained in the data base. To a certain extent this is true. However, the size and nature of the data base are different for different jobs, the transformations on the information are generally different, and the content and distribution of the final report may also vary. So the basic steps may be similar, but the job is defined, not by the steps, but by the data base, the transformations and the compilation and distribution of the final result.

In this section we will follow the format of section three and first discuss the individual functions of the researcher. Then in the next section, a progression of information systems to help him process information for each of the functions will be given. We note in passing that this functional approach tends to hide those information systems which link two or more of the basic functions. This combination of information systems may be desirable and can be built on the base described in this paper. We will attempt only a limited approach to this in section five.

The functions of a researcher which are discussed below are:

1. Search and Review
2. Calculation
3. Documentation
4. Administration

Search and Review.

The researcher usually has a problem either vaguely defined in his brain or in written form. He must perform many different types of information searches in order to further define the problem and/or to gain more information about it. Most researchers start this process by beginning with their most intimate data base, their brain. The next search is through their office file or books and then to the library or to appropriate colleagues. The process is repeated with their colleagues until relevant information is retrieved or the search is terminated. The search function is essential for a researcher and its actual operation depends on the particular data base which is being searched and the specific nature of the information desired.

In addition to the search function which is usually related to a particular problem, the researcher must also constantly review information which may not be related to any problem being studied at the moment. The information is usually in his field of specialty and is still important to him in a much broader sense in his attempt to stay informed. The review function is not as critical as the search function, but is definitely a function which centers around the processing of information and thereby is concerned with some type of information system. An example of the review function is exercised by many researchers when they periodically glance through the current abstracts of the literature in their field or scan the current issue of a professional magazine for an article of interest.

Calculation.

The real essence of research is the creative process. The best assistance which can be given to this uniquely human function is in terms of tools and techniques which might act as a catalyst or an accelerator for the process. One way to assist is to relieve the researcher of lengthy numerical calculations. If a means were provided the researcher to perform quick calculations (assuming calculations are necessary in his research), then this may in effect give him more time to perform his distinctively human activities.

Documentation.

Almost all professional jobs in a university require some form of documentation. The researcher, probably more than any other person, must commit his work and thoughts to written form in order to communicate his research to the world. For many technical people this is a time consuming and difficult function for them to perform. Because of this condition, pressure is building for the establishment of easy to use information systems which will assist the researcher in performing this function. A related function, dissemination, can also be handled by some of the information systems which are suggested to assist the researcher in documenting his work and preparing reports.

Administration.

Although university administration and its related information systems fall under another section of the paper (Administration Information Systems), sometimes administrative functions are performed by a researcher. Depending on the size of the project, the lead researcher may be responsible, not only for technical supervision, but also for some of the administrative functions related to it. He may be responsible for assignments of subtasks, for review of work performed, and even for subsequent evaluation of the capabilities of his subordinates.

The Research Data Base.

The University researcher must make extensive use of the data bases available to him. In the section on University Data Base the data bases used by university personnel were briefly discussed. In this section we want to investigate the scientific data bases in more detail. In particular, the library data base and typical individual data bases will be reviewed. We note in passing that the researcher has a need for certain types of information from the administrative data base, but even though this information is sometimes very important (e.g. budget figures for manpower and supplies), we will concentrate in this section on the high volume data bases through which he receives and transmits technical or researcher oriented information.

Library Data Base.

The university library is the central repository for information useful to most researchers. In fact the quality of research in many subjects is directly related to the amount of information contained in the library on those subjects. A good researcher may be effective with minimal library support, but he would be more effective with more information at his finger tips.

To effectively use the information stored in a library requires a number of skills which are not usually attributed to the typical university researcher. Since most libraries do not have an adequate supply of librarians to assist its users, it behooves the researcher to become his own librarian. For instance, a well equipped researcher should be familiar with and use the

- relevant abstracts and review publications in his field
- periodical publications and professional journals
- industry and government research reports
- other literature related to his particular subject
- interlibrary loan facilities in his library

There are many problems in searching for information in a library. Probably the most crucial is that of inadequate indexing. There are extremely large amounts of information which, though present in the data base, may never be found because they were indexed incorrectly or incompletely when they were initially added to the collection. If they are not stumbled on by chance when they are needed, then they might as well not be in the library. This problem is most prevalent in indexing multi-topic books under a single heading.

The research in library automation will provide for more flexible indexing procedures, and thus give the user more windows into the information base.

Other library related problems are the proliferation of the types of material on which library information is recorded and their ineffective utilization in a total system. Of course, paper is the chief material today, but the trend toward miniaturization and microform is increasing. This leads to more information packed into less storage space.

The effect is an added hardship on the researcher who may have to stand in line for a film reader, may have to use a reading device with inadequate lighting or can not easily get a copy made to peruse in his own office. These and other problems which inhibit the effective use of information in the library data base must be considered before establishing information systems for the researcher.

Individual's Data Base.

University researchers have a tendency to accumulate information of interest in their office for ready reference and quick recall. Over time the information which has been stored in a researcher's office may become rather extensive and may require an indexing system for its effective use. The information is accumulated for various reasons. Some material might be requested by him and be very pertinent to his research at a particular time. Other material might be forwarded to him for his retention and be of minimal use at the time he receives it. In reality the individual researcher's own data base is composed of those pieces of information which he feels are currently important or which may become useful to him in the future.

The indexing systems for these types of data bases vary considerably depending on the use made of them. If a researcher finds himself making extensive use of his own data base, then he will normally take the time to index and store the information in a manner which is consistent with his retrieval criteria. For example, if he tends to require information on a number of different subjects, then his data base might be stored in alphabetical order by subject. A more sophisticated system to handle a variety of different document forms (reports, newspapers, books, journal articles, etc.) involves using a subject oriented 3x5 index card file. When a new document arrives, a separate 3x5 index card is filled out for each subject discussed in the document. The document is given a number and this number is placed on all the index cards which refer to that document. The document is placed in a numerically oriented file and the index cards placed in an alphabetically oriented subject index card file. When the researcher requires information on a particular subject, he retrieves the index cards under that subject. They in turn contain a cross reference to the pertinent documents in hard copy file.

Because a researcher is to a large extent dependent on his data bases, it is imperative that he, at least, structure his individual files in a way amenable to his type of research and to his style of collecting and compiling information. Only after he has attempted to do this can he appreciate the enormously more complex problems inherent in structuring and retrieving information stored in an extremely large data base such as that contained in a library.

Information Systems for Research.

In this section each function of a researcher will be analyzed from the viewpoint of the information systems required for its effective performance. We will start the analysis of each function by looking at existing information systems and then extend the horizon until we reach some typical state of the art information systems which are within the scope and capability of today's systems. As we noted earlier, this functional approach may create some inefficiencies in that it does not recognize information systems which overlap functions. The effects of this shortcoming can usually be reduced in a later stage of the implementation process.

In order to reduce the scope of the research which resulted in this report, only the external information systems were considered. The internal information systems in the human body were not considered, nor was the creative process which is inherent in the mind of the researcher. Our concern was the external information systems which support and undergird the more subjective internal workings of the human.

The assumptions and conventions which introduce the section on Information Systems for University Teachers also apply in an analogous way to this section.

Search and Review Information Systems.

The search and review function is a rather broad one in that it implies a type of browsing capability as well as a capability to retrieve only those items of interest. In the discussion of the Individual Data Base a search and review information system was presented. The subject oriented card file provided the researcher a means of browsing through the index cards of information on a particular subject before he selected appropriate ones and obtained the corresponding documents.

The search and review function applied to the library data base is more involved. At present the browsing capability is performed by looking through abstract publications, thumbing through the card catalog or scanning the titles while walking through the stacks. The retrieval function is similar in that the browsing usually leads to the selection of particular items for more intensive study. The major problem in performing this function today is a combination of frustration and unnecessary time consumption. It is frustrating to know that your library must have many relevant pieces of information to help you in your research and that you may only be able to find a few of them. It is also inefficient for a researcher to make library searches which make minimal use of his intellectual capability.

Several proposals have been made to automate the indexing and abstract systems in the library. If a workable system were implemented, it would reduce the need for researchers to collect information in their individual files. An automated indexing and abstract system would contain an appropriate index and abstract record in the computer's files for each document in the library. One proposal is that a researcher need only state his request on a cathode-ray tube (CRT) terminal in the request area in the library. The computer will search its files and display the results of the search on the CRT. Means could be provided to narrow the search if it resulted in too many document references or enlarge it if it resulted in too few references. After the researcher has sufficiently browsed through the related indexes and abstracts, he can request a hard copy printout of only those document numbers he wishes to review in detail for his use in locating the documents in the library stacks. Transport systems have also been proposed to automatically select a book from the shelf and deliver it to the requestor.

A number of increasing capabilities can be added to the above information system, but the great expense required to implement even the basic system has dampened the enthusiasm of many practical librarians. For example, terminals may be placed in research centers as well as in the library. Also the man-computer interaction at the terminal can be such that the computer programs would lead the researcher through the indexes and abstracts. Because of the complexity of the storage and indexing problems, this type of information system is not yet a complete reality, but research continues.

Calculation Information Systems.

Some researchers are required to perform repetitive or algorithmic tasks which can be performed more accurately and cheaply by a calculator or a computer. As we mentioned in our discussion of Teacher Information Systems, devices for coping with these tasks should be provided the researcher.

The use of digital computers, accessed through remote terminals, are becoming popular tools of university researchers. However, much more is required than just the remote physical connection between the terminal and the computer. The computer must have the appropriate computer programs to handle many different types of calculation requests. The usual FORTRAN or ALGOL languages should certainly be provided for those researchers interested in mathematical computations, but there should also be provided a storage and retrieval capability, a collection of simulation languages, statistical routines, and other existing programs which might be useful to the researchers in a particular university.

Documentation Information Systems.

The usual information system for documenting the results of research is based on the standard, hard copy, pencil and paper approach. In fact this paper was written using this approach. First the information is written on paper and quickly reviewed, then it is typed in draft form, manually edited, and then typed in final form. There are other ways of processing the information which result in various kinds of efficiencies. Unfortunately the alternatives always appear to be more costly. Happily this is not always the case, but to establish this fact takes a cost analysis of the particular system in question.

In the section on composition and reference information systems we discussed systems which helped the teacher in his composition of material for his class. Those systems are also valid for use by the researcher in documenting his research. The final document will probably be longer for a research report than for class notes, but the use of the previously discussed systems would be approximately the same.

The automatic dissemination information system which was discussed in the teacher section is of great importance to the researcher. He needs a system which will automatically route pertinent current information to his office. He should be provided this service in the same manner that the service is provided the teacher. See the section on course design/revision information systems for a short description of an information system which would provide this capability.

Administration Information Systems.

Many university researchers find themselves in a partial administrative role in the performance of their daily tasks. They require information, when performing these duties, from various data bases and the operations they perform on the information is considerably different from that performed on research-oriented information. Thus, the researcher is in need of some type of information system to handle this administrative information.

We naturally look to the Administration Information Systems presented earlier in this paper for some solution to this need. We find several data bases (e.g. Employee, Financial, Planning, etc.) which may be of interest and we find in the section on the Conceptual Design of an Administrative Storage and Retrieval System that the Administration Information System will have the capability of serving two types of users — those who need periodic reports and those who desire an on-line access to the summary files. The researcher with administrative duties would probably require both of these capabilities and the reader is referred to the section on The Conceptual Design of An Administrative Storage and Retrieval System for a discussion of their use.

The Total Design of a Research Information System.

The concept of a Total Research Information System is based upon unity and organization of the data base elements and complete communication between the researchers and this data base. See Figure 5 for a sketch of the relationship of the researcher information system with the major data bases in the university. Such a system requires a unified

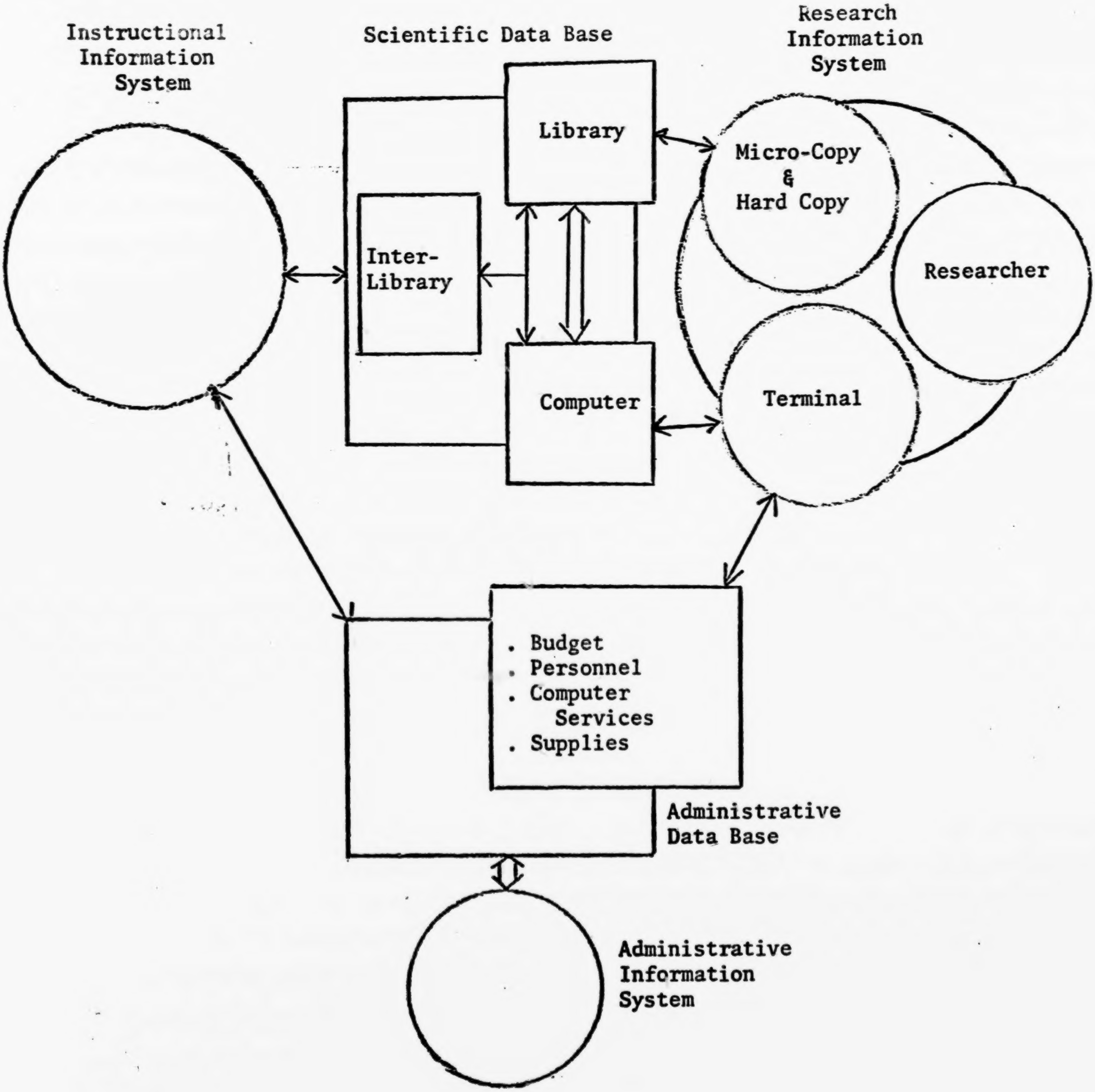

Instructional Information System
Scientific Data Base
Research Information System
Library
Micro-Copy & Hard Copy
Inter-Library
Researcher
Computer
Terminal
. Budget
. Personnel
. Computer Services
. Supplies
Administrative Data Base
Administrative Information System

Figure 5

library data base which is accessible, both manually and automatically, by every researcher. There should be a form of automatic dissemination such as that discussed in the section on Course Design/Revision Information Systems. In this way the researcher is kept abreast of developments of others in the university, and elsewhere, with respect to his field and his specific project.

He should have easy access to the computer, preferably from a display terminal in his office. This, along with some form of microreader, would be his main information input devices. He could store and search information in both his individual library and the main library through this terminal. Searching could be done by author, title, or subject (concept). One type of response from the system is a list of abstracts of those documents which are pertinent to his request. Once the computer determines which documents he desires, these documents could be sent to him at a later time in hard copy or micro image form.

Technical researchers would be able to write their own programs and calculate from their terminals -- desk-calculator style, and to debug or combine existing or new programs. Access to the administrative data base in order to determine available finances or personnel could be directed from this terminal via dial-up to the central computer.

The computer can also be used to assist the researcher in documenting his projects. When a project is completed, the computer could assemble the accumulated documentation and prepare this data for formal printing of the project reports. Computer programs can also be constructed to index the reports automatically and then add all results to its own data base.

Operating in this manner under a Total Research Information System is simply making the maximal use of all available tools for the researcher and assuring proper communication between all similarly oriented persons. None of the concepts here is beyond the current state of the art. The programming necessary to combine all of these functions into one system does tend to stagger the imagination, but with the larger and faster storage systems being developed and more sophisticated programming techniques becoming available, it is not at all unreasonable to start preparing for their effective use now.

Recommendations.

In this section we give summary list of recommendation which can be used as a checklist in the development of information systems for university researchers. The list is not exhaustive, but it represents the major areas of immediate concern for those people interested in upgrading the information processing activities of researchers.

The recommendations are all related in some way to the use of a computer in helping a researcher perform his tasks faster and more easily. To accomplish this an extra expense necessarily is added to the system and herein lies the rub. Most universities are not solvent enough to absorb the increased expense associated with the effective use of computing equipment. But the use of the computer and its associated information systems is the next logical step in the emancipation of researchers from laborious and time-consuming tasks.

1. Establishment of a University-wide Information Center

This recommendation was made in the section on Recommendations for Teacher Information Systems with reference to screening and disseminating general literature to university teachers. The same center could also perform this function for university researchers. The operation could begin with manual screening and dissemination and evolve into a fully automatic system. This recommendation, in effect, is not only to establish such a center in each university, but to provide for its evolution into a completely automated, inter-university system.

2. Establish Computer Software for Office Terminals

Again, as in the section on Recommendations for Teacher Information Systems, we recommend that the researcher be provided the processing power of a computer in his office. This means that he needs a readily accessible terminal to request jobs of a computer, and he needs a sophisticated programming system in the computer to back him up. He must be able to utilize the computer in as many ways as possible to assist him in his research. Refer to the previous section on Recommendations for a discussion of the computer software support for office terminals.

3. Establish an Automated Index and Abstract System for the Library

University libraries operate under enormous constraints, but somehow manage to control their repositories of information. However, to a researcher, control is not enough. He must have as much relevant information as possible in order to do his most effective work. Therefore more powerful techniques are required to obtain a better hold on the library data base. One of these techniques centers around a system which contains an appropriate index for every document in the library. Each document can also have an abstract associated with it. Obviously it would be expensive to keep all this information in a computer's files and to program the computer to use it in answering requests. Therefore somewhat cheaper and less expensive approaches must be made in an evolutionary system which someday could result in a completely automated system.

The first step is to recognize the problem and the fact that it is becoming more critical each year. Secondly, existing abstracts and/or reviews can be automated in step by step fashion to provide some background and experience in implementing such a system. Thirdly, all articles which arrive in the library should have an author's abstract and at least a key word index attached. Next, the library could require that these indexes and abstracts be in a certain machine readable form. And finally, the necessary software programs should be written (and the computer purchased) to operate the system as required by the librarians and users. Needless to say, the final product may be within the state of the art, but it is far too expensive for a university library. The first steps, however, are not expensive and would begin the process.

4. Establish Systems to Help the Researcher Compose and Document His Work

The paper and pencil approach to documentation will be with us for years to come, but there are other methods which take less time and are just as effective. Many researchers are using tape recorders for the narrative part of their reports. However, the computer represents the best approach to the entire documentation and production process.

Someday in the future a researcher will use a CRT/typewriter device to compose his reports. The computer will suggest alternatives and choices of words, correct misspellings, format the material, be directed to delete or insert sections, and prepare the final version for printing. It could also be programmed to suggest keywords for the index, automatically index or abstract the document, and disseminate the document to interested parties.

SUMMARY

In this report we have represented three total information systems (Administrative, Teacher, and Research), but somehow these total systems must be finally collected into an even larger system and viewed as a single entity — the university itself. It is possible to continue this progression, for the university is part of a larger system, but for this report we consider the boundary of the university as the limits of our study.

In establishing these information systems, we observed a number of places where one type of user processed information from data bases used primarily by another. For example, the administrative data base, which is created and maintained by the administrators of the university, also contains information related to teaching (e.g. student information) and to research (e.g. faculty and budget information). A second example is the automatic dissemination of general literature information to both teachers and researchers. And finally a third example is the use of remote terminals for computational work by students, teachers, and researchers. These few selected examples from the many which are present demonstrate the fact that it is one system which is being discussed and not three independent ones.

The computer represents the major integrating force in university information systems. Due to such established software techniques as timesharing, modular programming, and conversational computer languages, it becomes obvious to the designer that there is really only one administrative data base and threfore, for example, only one copy of a student's record need be kept. Any person authorized to look at this record may do so through the remote terminal in his office. So why should a separate record be kept in the dean's office, the department's office and in the central files? Why not just one completely current one in the computer which is accessible by all? The answers to these questions lead one to establish a centralized system of the type discussed in this report.

How would such a total university-wide system work? Let's examine the answer from the viewpoint of the operations performed by the computer.

First we must have a time shared programming system to allow for on-line requests. This programming system must provide for "conversational" dialogue between the user and the computer. The user may request some type of storage or retrieval operation, or he may use the computer to make numerical calculations. He may write programs, debug programs, store programs, delete programs and in general do whatever he desires with his own individual data base. Computer-assisted instruction would also be provided through the on-line system.

The computer must also be capable of handling a number of background or batch operations. Payroll accounting, periodic budget reports, class rolls, etc. can all be handled in an interleaved fashion with the time-sharing activities. Automatic abstracting or automatic dissemination are library-oriented functions which can be performed as a batch operation.

The storage requirements on the central computer would be very high if large quantities of scientific information were required to be stored in the computer. Abstracts and indexes of documents (instead of the documents themselves) would help alleviate the problem, but even a greater number of abstracts would eventually start to overflow the memory of most computer systems. Until sufficient high volume computer storage becomes technically feasible and inexpensive, we must be very selective and allow only the critical scientific data base elements to be stored in machine readable form.

The design and implementation of the systems discussed in this paper are possible today. This is not to say that there are no difficult problems in establishing such a complex system, but the computers, the programming experience, and the methodologies of complex systems design are available in the market place. Only two real problems remain: cost and acceptance. The problems of both may be reduced over time, but acceptance is a function of expert training and meaningful practical demonstrations of the usefulness of well-designed computer-based information systems. An ancient Chinese philosopher may have advice for us today when he said "A thousand mile journey always begins with a first step."

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